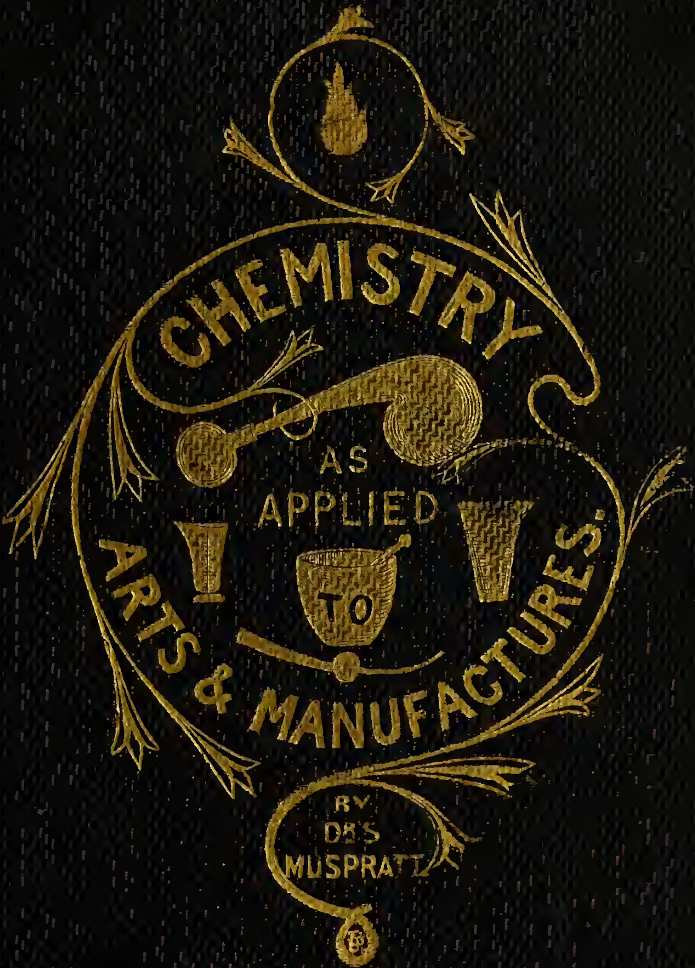

CHEMISTRY AS APPLIED TO ARTS & MANUFACTURES.

BY
DR.S
MUSPRATT

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Th. Vretto

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Chemistry

THEORETICAL, PRACTICAL & ANALYTICAL,

AS APPLIED AND RELATING TO

The Arts and Manufactures.

BY

DR. SHERIDAN MUSPRATT, F.R.S.E. M.R.I.A. F.G.S.

VOL. I.

William Mackenzie.
Glasgow. Edinburgh. London, and New-York.

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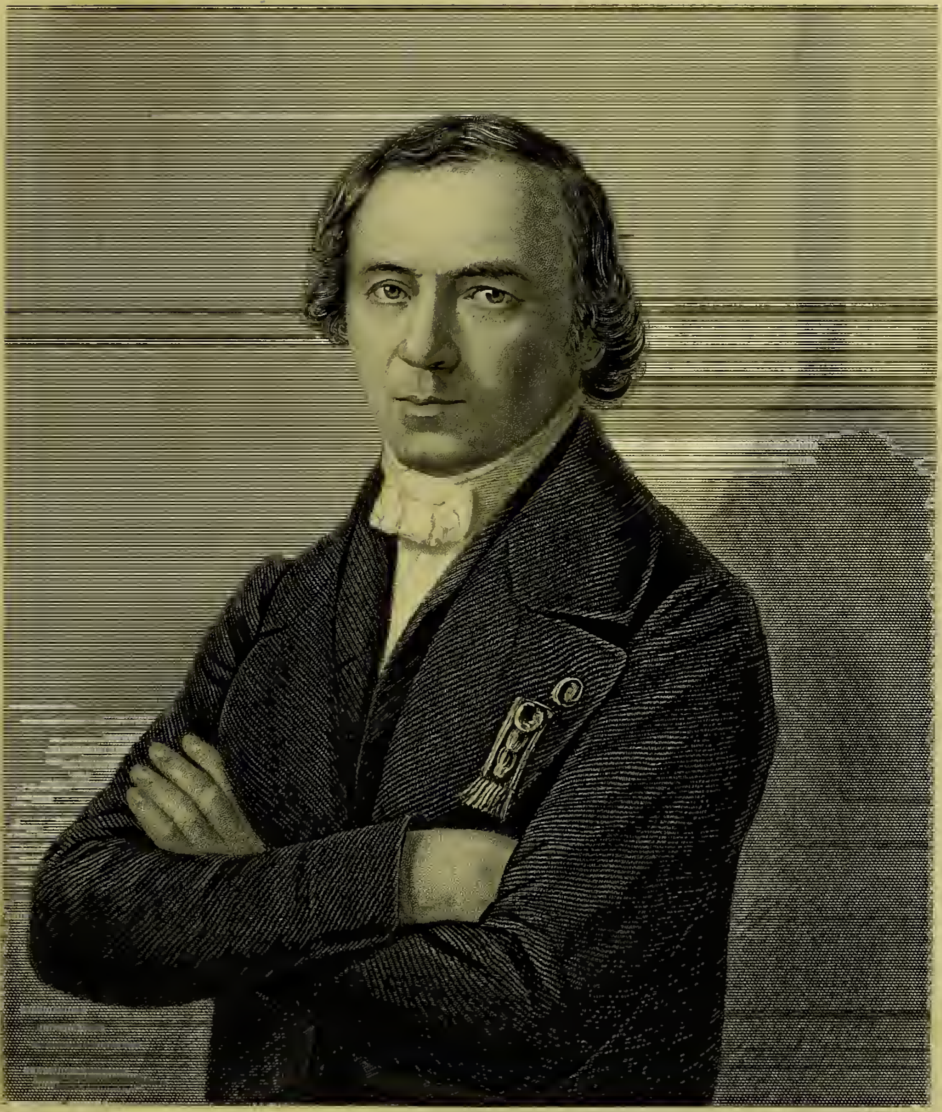

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CHEMISTRY,

THEORETICAL, PRACTICAL, AND ANALYTICAL,

AS APPLIED AND RELATING TO

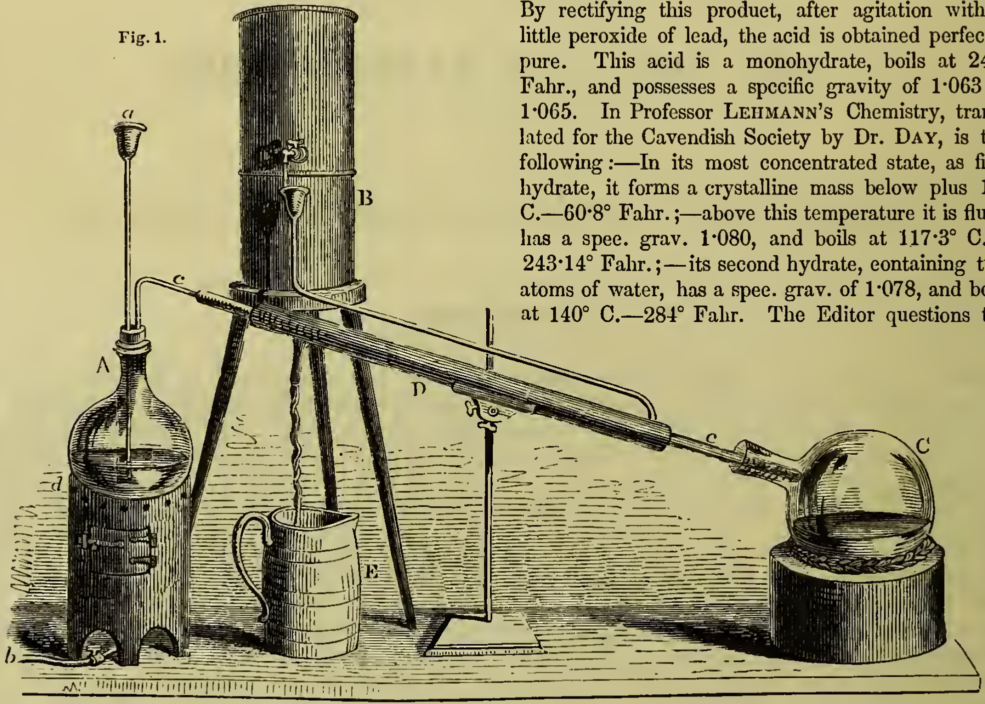
THE ARTS AND MANUFACTURES.

There are qualities in the products of Nature yet undiscovered, and combinations in the powers of Art yet untried. It is the duty of every man to endeavor that something may be added, by his industry, to the hereditary aggregate of knowledge and happiness.—Dr. Johnson.

ACETIC ACID.

ACETIC ACID—*Acide Acétique*, French; *Essigsaure*, German; *Acidum Aceticum*, Latin; *Eisel*, Saxon—is the name of the acerb principle existing in vinegar. It has been known from time beyond memory, that the expressed juice of fruit, after becoming vinous by a species of fermentation, was, under particular circumstances, found to undergo another change; that is, it became acrid to the taste—a conversion we now call the *acetous fermentation*, and the acid produced, *acetic acid.* Under the name *vinegar*, this acid was known many ages before the discovery of any other, those only excepted which exist ready-formed in the vegetal kingdom. It appears, from the writings of MOSES, that it was in very general use among the Israelites, and other Eastern nations, at a very remote period; there existed, however, no definite knowledge with regard to the nature of its formation, and even in the commencement of the eighteenth century, great ignorance was manifested as to the cause of its production. At this early date, when comparatively very little was understood of chemical science, it was impossible to investigate the theory of these changes, owing to the number of substances contained in the liquids, and the great variety of circumstances producing such metamorphoses. With all the advantages which chemistry holds forth, there are many points still remaining to be cleared up in some of the practical details of the *acetous fermentation;* however, we are enabled to lay down one principle as its cause, in all the processes for making acetic acid, with the exception of its formation in the distillation of wood. The alchemists were acquainted with this acid in a concentrated state, as *radical vinegar*, or *vinegar of Venus;* and the product of the rectification of this liquid they named *distilled vinegar*, or *acetous acid.* BERTHOLLET, in 1785, published a paper wherein he endeavored to demonstrate that the acid obtained from the distillation of verdigris—acetate of copper—was different from *acetous acid*, as then known, both in physical characteristics, as well as in its affinity for other bodies, in forming neutral compounds with them. The phlogiston theory being at this time in the ascendant, BERTHOLLET concluded that, during distillation, the acetous acid gave out phlogiston to the copper, and received oxygen in return; hence it was assumed that the new liquid was acetous acid united with oxygen, and was accordingly named *acetic acid.* After the phlogiston theory had exploded, the views of BERTHOLLET were not materially altered on that account, for, the residue in the retort being metallic copper, it was supposed that the acetous acid deprived the oxide of copper of its oxygen. STAHL and WESTENDORF were the first to prepare the acid in a pure state, but LÖWITZ was the first to obtain it as a pure hydrate of acetic acid in 1793. Afterwards, it was observed by Dr. J. DAVY, that spongy platinum, in contact with the vapor of alcohol, became incandescent, and generated this acid. DÖBEREINER further studied the nature of the acid, and proved that the alcohol was oxidized at the expense of the atmospheric air, producing acetic acid and water, and that no carbonic acid was formed—thus pointing out the fallacy of the opinion held by the chemists of his time, that carbonic acid was one of the products of the acetous fermentation. Further, he showed that, for the complete oxidation of one atom of alcohol, four atoms of oxygen were required. This acid is produced under various circumstances, and in a variety of ways, some of which are, in a theoretical point of view, extremely important. When alcohol is treated with hot potassa-lime, hydrogen gas is evolved, and acetate of potassa is formed. Cane sugar, on being boiled with a concentrated solution of potassa, eliminates hydrogen, and gives rise to a series of acids, the principal of which are acetic and oxalic. The pure acid is obtained by distilling acetate of soda or potassa with sulphuric acid. Fig. 1 is an apparatus well adapted for this purpose. A is a flask, closed by a cork, which receives two tubes; one of these is a funnel tube, *a*, through which the liquid bodies are introduced, and the other conducts the vapors to the condenser. This consists of an outer case, D, through which the tube, *c c*, connected with the bent tube from the flask, A, passes. The condenser is cooled by keeping a stream of water running constantly from the reservoir, B; C is a flask to receive the condensed vapors; *d* the gas lamp which heats the liquid in A, *b* the gas pipe, and E the vessel into which the heated water flows from the condenser. A convenient quantity, say half a pound, of pure acetate of soda, is introduced into the flask, and about five ounces of strong sulphuric acid, sp. gr. 1·80, poured in through the funnel, *a*, and the whole well agitated. Sufficient heat is developed to cause one-eighth of the acid to distil over without fire, and the heat of the sandbath is sufficient to expel the rest. A colorless liquid is obtained, which has a specific gravity of about 1·061, and contains forty to forty-two per cent. of real acid. By rectifying this product, after agitation with a little peroxide of lead, the acid is obtained perfectly pure. This acid is a monohydrate, boils at 248° Fahr., and possesses a specific gravity of 1·063 to 1·065. In Professor Lehmann's Chemistry, translated for the Cavendish Society by Dr. Day, is the following:—In its most concentrated state, as first hydrate, it forms a crystalline mass below plus 16° C.—60·8° Fahr.;—above this temperature it is fluid, has a spec. grav. 1·080, and boils at 117·3° C.—243·14° Fahr.;—its second hydrate, containing two atoms of water, has a spec. grav. of 1·078, and boils at 140° C.—284° Fahr. The Editor questions the accuracy of the above. In all other chemical works, the specific gravity of the monohydrated acid is given as 1·063. It is strange that Dr. Day should not, in a note, have alluded to this apparent error. The acid with one equivalent of water has the composition—

Fig. 1.



	Atomic Weight.		Centesimal Quantities of each.
4 Eqs. of carbon,	24	=	40
3 Eqs. of hydrogen,	3	=	5
3 Eqs. of oxygen,	24	=	40
1 Eq. of water,	9	=	15
	60		100

Formula, $HO, C_4 H_3 O_3$.

For a long time it baffled the labors of the chemist to obtain the acid *free from water*, every available means applied proving unsuccessful. Lately, however, Gerhardt has produced the anhydrous acid, by mixing chloride of benzoyle and fused acetate of potassa in a flask, and allowing them to heat on a sandbath. Chloride of potassium is first formed, and a substance which is probably acetate of benzoyle; but the action does not stop here, since, on heating the mixture above this temperature, with an excess of acetate of potassa, the first-mentioned bodies react upon each other, and there distils a perfectly colorless iridescent liquid, having the unmistakeable odor of acetic acid. This liquid is anhydrous, boils at 279·5° Fahr., is heavier than water, in which it sinks as an oil, and at the temperature of 58° or 60° they are immiscible. Hot water changes it into ordinary acetic acid. The odor of acetic acid is most peculiar—suffocating, but when mixed with air agreeable; it is nearly as acrimonious as sulphuric acid; when dropped on the skin it acts like an escharotic, producing much heat and rapid inflammation of the part with which it is in contact. Cold acetic acid is not inflammable, but when boiled its vapor ignites, burning with a blue flame. It distils without change—even a red heat only slightly decomposes it. When its vapor is passed through tubes containing red-hot charcoal, it suffers decomposition rapidly, giving rise to carbonic acid, carbonic oxide, carbide of hydrogen, and water.

Acetic acid, with most bases, gives salts soluble in water and in alcohol; even acetate of lead is soluble in the latter—a few neutral acetates only are sparingly soluble. A solution of nitrate of silver is not clouded by free acetic acid; but it is troubled by saturating the free acid with ammonia.

Subnitrate of mercury determines at once, in acetic acid, a crystalline precipitate. Acetic acid does not reduce the terchloride of gold, even in the heat; but if an excess of potassa be added, metallic gold is immediately deposited.

Acetates tinge the sesquisalts of iron blood-red. Free acids, except acetic acid, destroy this color. Of all the volatile organic acids, acetic acid is the only one having the property of dissolving protoxide of lead, in the state of a basic acetate, which solution, when the oxide of lead is in excess, has an alkaline reaction on reddened litmus paper—a characteristic test.

The specific gravity of the acid is variable, the monohydrate being 1·063, while the same acid diluted with five atoms of water, or fifty-one and a half per cent., possesses the like specific gravity. Hence, in determining the strength of acetic acid, the density is no criterion of the amount of acetic acid present, as is shown in the subjoined table, drawn up by Thomson :—

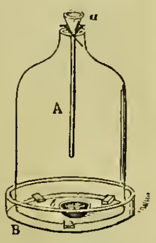
Equivalents of Acid.		Equivalents of Water.	Sp. Gr. at 60°.
1	+	1	1·06296
1	+	2	1·07060
1	+	3	1·07084
1	+	4	1·07132
1	+	5	1·06820
1	+	6	1·06708
1	+	7	1·06349
1	+	8	1·05974
1	+	9	1·05794
1	+	10	1·05439

From the following table it will be seen, that when it is required to determine the amount of dry acid in rather dilute solutions, the specific gravity test answers pretty well within certain limits; but when the acid increases in strength, it is evident from the preceding that this test is fallacious, as the acid containing only *one* atom of water, and that with *six* atoms of water to one of acetic acid, are of the same density.

Hydrated Acid in 100 parts.	Sp. Gr.	Hydrated Acid in 100 parts.	Sp. Gr.	Hydrated Acid in 100 parts.	Sp. Gr.
100	1·0635	67	1·0690	34	1·0450
97	1·0680	64	1·0680	31	1·0410
94	1·0706	61	1·0670	28	1·0380
91	1·0721	58	1·0660	25	1·0340
88	1·0730	55	1·0640	22	1·0310
85	1·0730	52	1·0620	19	1·0260
82	1·0730	49	1·0590	16	1·0230
79	1.0735	46	1·0550	13	1·0180
76	1·0730	43	1·0530	10	1·0150
73	1·0720	40	1·0513	7	1·0107
70	1·0700	37	1·0480	4	1·0050

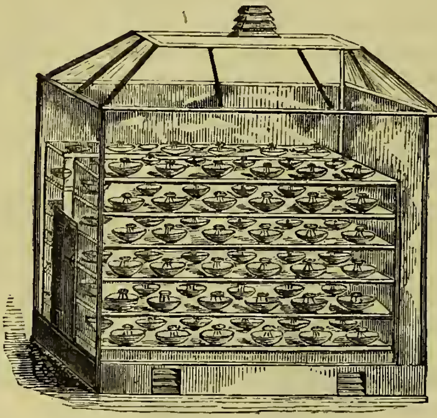
The method for testing the strength of acetic acid, *et cetera*, is fully described under Vinegar, page 32. This acid is without doubt the most interesting of all the organic acids, as it enters more than any other into the industrial arts, and occurs the most frequently in nature, ready formed in several products of the vegetal kingdom. Acetic acid exists in the sap of nearly all plants, and probably in divers liquids dependent on the animal economy; but is never found in any large quantity. Several organic matters give birth to this acid during their decomposition. It is also produced by the putrefaction of animal and vegetal substances; the action of the alkalies, at an elevated temperature, converts some vegetal acids into acetic and oxalic acids —in fact, nearly all the bodies of an organic nature produce acetic acid when submitted to distillation. Besides the processes already glanced at for the production of acetic acid, a variety of others are resorted to for its formation. An interesting method, on account of its beauty and perfection, is the oxidation of alcohol, through the agency of spongy platinum. It is a well-known fact, that spongy platinum—platinum black—from its minute state of division, condenses within its pores several hundred times its volume of atmospheric air; consequently, when the vapor of alcohol comes in contact with this body, a supply of oxygen in a concentrated state is presented to it, and the platinum, without losing any of its inherent properties, effects chemical combination; the alcohol undergoing slow combustion, and being converted into acetic acid. This can be illustrated by an apparatus similar to Fig. 2,—A is a bell glass, through the mouth of which a long funnel, *a*, passes; the lower end of this funnel terminates in a fine point, so that the alcohol poured in may percolate very slowly. The vessel is placed upon supports, *b*, within a dish, B, in which is a saucer or small flat basin, containing the spongy platinum. The interstice from the bottom of the dish, B, and the bell, A, serves for the circulation of air in the jar. On pouring the alcohol through *a*, in the course of a short time the odor of acetic acid is perceived at the mouth, from the acetic acid vapors which are generated. These condense on the sides of the jar, and trickle to the bottom, where they collect in B. It is advantageous, for the success of the experiment, to have the alcohol heated to about 90° Fahr. when it is poured in. In Germany, and other continental countries, where the duty on alcoholic liquors is not so high as in England, this method was once successfully followed, and for excellence and simplicity it can scarcely be surpassed. For operations on a large scale, a glass case, or one of wood, is constructed, the roof of which is of glass to admit the heat of the sun. In the interior of this case shelves are contrived, twelve inches apart, on which a series of shallow glazed earthenware or porcelain dishes are placed. The alcohol is poured into these vessels, and in each is a porcelain or stoneware tripod, bearing a watch-glass or small dish, containing the spongy metal. No more than an inch and a half, or two inches, should intervene between the platinum in the watch-glasses and the surface of the alcohol in the flat dishes. If there be no arrangement to supply an influx of air, in the place of that which becomes deoxidized, no more alcohol should be operated upon than the volume of air in the apparatus will be capable of converting into acetic acid. This quantity may be inferred from the fact, that one hundred and ten grains of alcohol require for their complete oxidation one thousand cubic inches of air, producing one hundred and twenty grains of anhydrous acetic acid, and about sixty-five grains of water. If a draught be instituted, by which the vitiated or nitrogenous portion of the deoxidized air is withdrawn, and

Fig. 2.



fresh quantities supplied by means of air-passages in the lower part of the chamber, the necessity of observing, with the accuracy mentioned previously, the amount of alcohol submitted to oxidation, is obviated. This arrangement is shown in Fig. 3. The temperature of the air in the case is raised by means of steam pipes or flues, from a fire adjacent to the apparatus, similar to those in vineries in this country, to about 90° Fahr.; oxidation of the alcohol commences, which is ascertained by the pungent odor of the acid. The elevated temperature converts a portion of the alcohol into vapor, which, on coming into contact with the moistened platinum, undergoes incipient combustion, giving rise to the acid. These vapors condense, and are collected, for the most part, in the dishes; the remaining quantity trickles down into a receiver at the bottom of the case. In this manner, the whole of the alcohol, in a comparatively short time, is converted into acetic acid; and as long as a supply of fresh air is kept up in the chamber, the spongy platinum retains its activity by inducing the oxidation of the liquid. With a case of twelve cubic feet capacity, and seven or eight ounces of platinum black, one pound of absolute alcohol may be acetified daily; and with a provision of twenty-four or thirty pounds of spongy platinum, and a proportionate sized case, three hundred pounds of alcohol may be oxidized in the same time, producing an acid of the purest kind. Hence this method claims pre-eminence over any other for the formation of acetic acid. The theory of this conversion of alcohol into acetic acid may be understood from the following representation. In the first stage of oxidation, the alcohol loses two atoms of hydrogen, which, by uniting with the oxygen of the air, give rise to water; there remains a peculiar volatile compound—aldehyde—which is the oxide of the supposed radical of acetic acid. The symbolical formula expresses this change:—

Fig 3.



$$\underbrace{C_4\,H_5\,O,\ HO}_{\text{Alcohol.}} + O_2 = \underbrace{C_4\,H_3\,O,\ HO}_{\text{Aldehyde.}} + 2\ \text{aq.}$$

The aldehyde takes up, in addition to the oxygen which it constitutionally contains, two atoms more, and thus passes into acetic acid, as is shown in the annexed equation:—

$$\underbrace{HO,\ C_4\,H_3\,O,}_{\text{Aldehyde.}} + 2\ \text{aq.} + O_2 = \underbrace{HO,\ C_4\,H_3\,O_3}_{\text{Acetic acid.}} + 2\ \text{aq.}$$

The following also represents the transformation:—

			Numerically.
1 atom of alcohol..........	=	$C_4\,H_5\,O,\ HO$	= 46
Minus 2 atoms of hydrogen.......	=	H_2	= 2
Equal 1 atom of aldehyde.........		$C_4\,H_3\,O,\ HO$	= 44
Plus 2 atoms of oxygen.........	=	O_2	= 16
Equal 1 atom of hydrated acetic acid		$C_4\,H_3\,O_3,\ HO$	= 60

Aldehyde is an exceedingly volatile body, a very slight heat being sufficient to dissipate it; and if this be not prevented by having a copious supply of fresh air in the case to oxidize it, a loss is suffered by the manufacturer. Every hundred parts by weight of alcohol require for oxidation sixty-nine parts of oxygen, producing one hundred and ten parts of acetic acid and sixty parts of water.

In every instance where alcohol or fermented alcoholic liquors are acetified, the principle of the conversion is the combustion of the alcohol of those liquors, by combining with oxygen. It has been stated that spongy platinum induces this change in regard to alcohol, but the same result is attained when other alcoholic liquids are exposed to the air at a slightly elevated temperature, in contact with a body in the state of fermentation, and in several other ways—which change has been called the *acetous fermentation.* In this manner, wine, brandy, beer, and, in fact, all liquids which undergo the vinous fermentation, are converted into solutions of acetic acid; and many liquids apparently pass at once into the acetous fermentation, especially those eviscerating a quantity of mucilage, and very little sugar. Alcohol in a pure state does not suffer the acetous fermentation, but if it contain vegetal matter, a metamorphosis occurs on its exposure to the air; hence the cause of the souring of wines, and the reason why weak ones do so sooner than strong, the former containing little spirit and much vegetal matter, while with the latter the case is contrariwise. If the vinous fermentation has completely ceased in those liquids, subsequently clarified, when exposed to the air at an elevated temperature they do not acetify; but if a ferment, in the shape of yeast, honey, or strong vinegar, should be added to such liquors; then, on the application of slight heat with access of atmospheric air, the intestine motion commences.

In all cases of acetous fermentation, where a quantity of liquid is exposed to the air, oxidation takes place at the surface only, and this occasions the conversion of their alcohol into acetic acid to extend over several weeks, or even months. Heat very much accelerates the change, inasmuch as a portion of the alcohol is converted into vapor, and this, carrying with it some of the ferment, in a state of eremacausis, communicates the same property to the vapor likewise, and acetic acid results; besides, imperceptible currents form in the liquids, by which fresh surfaces are always exposed till the work is completed. Spiritous liquors, on being exposed to the air in a state of fermentation, or with a ferment added to them, though ever so clear at the first, speedily become turbid, and slimy filaments appear through the solutions, which gradually adhere and rise as a spume to the surface. When this spume incrassates, it precipitates to the bottom of the vessel, and is called *mother of vinegar*. During the formation of this body an elevation of temperature is observed, a peculiar aromatic odor is evolved, and an acid reaction acquired; and towards the end of the operation, the temperature falls to about that of the surrounding air, the liquor clarifies, and, when it is siphoned off, constitutes the well-known liquid, Vinegar.

Before entering upon the manufacture of vinegar, it is deemed advisable to introduce the remarks of Dr. Ure relative to the acetous fermentation. They are clear and erudite, and may at some time or other prove serviceable to the consulter of these volumes.

Hitherto it has been generally imagined, that the formation of vinegar is accomplished by a peculiar fermentation, which has been called the *acetous*, in contradistinction to the *vinous*, the *panary*, the *putrefactive*, *et cetera*. But this doctrine is doubtful. The experiments serving as its basis, and which should reveal the nature of its peculiar ferment, as also the chemical reactions taking place in its progress, all seem to place this phenomenon somewhat out of the sphere of fermentation, properly so called. Every fermentation operates by resolving a body into compounds less complex than itself. But the so-called acetic fermentation serves to combine, on the contrary, two bodies, namely, alcohol and aldehyde, with the oxygen of the air; and this is the only case where fermentation produces such an action, which is a true combustion.

Yet it must be confessed, that the acetic seems to possess all the characters of the other fermentations; *videlicet*, the union of an organized body, or ferment, with a fermentable organic matter. The former is found in that spumous substance called *mother of vinegar*, and which is seen floating on the surface of vinegar in the act of its generation. With the acid fermentation it begins to appear, and it continues to be formed during its whole progress. It is at first a pellicle, composed of globules much more minute than those which constitute yeast; and they are often irregularly grouped. The pellicle becomes afterwards thicker in body and consistence, exhibits more distinct granular forms, and acquires a tendency to be distributed in strips or narrow bands. Of the reproduction of these globules the mode is quite unknown, but they seem somewhat akin to the slimy deposit of sulphurous mineral waters, called *baregine*.

If the study of the acetic ferment be mysterious, it is, nevertheless, clear that the conversion of alcohol into vinegar never takes place, in the common process, without the presence of an albuminous substance, and of the conditions favorable to all fermentations, besides the necessary access of air, not only at the commencement —as suffices for the vinous—but during all its course. Hence every weak spirituous liquor, which contains an albuminous matter or any ferment, may, with contact of air, and a temperature of from 60° to 90° Fahr., give birth to vinegar. If the mixture be too rich in alcohol, or if the nitrogenized matter be absent, or if the temperature be much above or below these two points, the phenomenon of acetification ceases. There are, therefore, several indications of the existence of a peculiar vinegar fermentation; though it should be observed, that the production of lactic acid—as from fermenting cabbage, starch, *et cetera*—has sometimes misled chemists into the belief of an acetic fermentation. The Editor will, on this account, point out briefly the distinction between the two processes.

The *acetic fermentation* requires the presence of ready-formed alcohol and the air; the *lactic*, on the contrary, proceeds with starchy or saccharine mixtures, without the intervention of alcohol or of atmospheric oxygen; and, when once begun, it will go on of itself. Acetification presents, moreover, a striking analogy with the phenomenon of nitrification, in the necessity of an elevated temperature, and the influence of porous bodies to divide the particles of the liquids and the air. Gaseous ammonia, for example, mixed with oxygen, when passed through a tube containing spongy platinum slightly heated, becomes nitric acid; when sulphurous acid gas and oxygen are passed through hot pumice stone, they become sulphuric acid; and when lime or potassa, diffused through porous matter, is placed in contact with ammoniacal emanations in the artificial nitre beds or nitrifiable soils, nitrate of lime or potassa is formed. In like manner, under the influence of spongy platinum, alcohol and air may, by a true oxidizement of the etherous part of the alcohol, produce aldehyde, which passes afterwards into acetic acid and water; as is, hereinafter, represented:—

$$\begin{array}{llcl}
\text{Thus alcohol, } C_4H_5O, HO = & C_4H_4O, & + & H_2O \\
\text{Plus two of oxygen, ...} & \underline{\quad\quad O} & & \underline{\quad O} \\
\text{Equal aldehyde, ...} & C_4H_4O_2, & + & H_2O_2 = 2\,HO, \\
\text{Plus two of oxygen, ...} & \underline{\quad\quad O_2} & & \\
\text{Equal acetic acid, ...} & C_4H_4O_4 + 2\,HO = C_4H_3O_3 + 3\,HO. & &
\end{array}$$

Donovan gives some interesting details upon the phenomena of the acetous fermentation, and as they differ in the main point from those of other chemists, extracts from them are appended, with a few observations by the Editor, showing how far they may be relied upon.

With regard to the theory of the acetous fermentation, and the formation of vinegar, little is certainly known. It may be admitted as a fact, that it is almost exclusively the alcohol of the fermented liquor which is changed into acetic acid; and the query is,—What is the nature of the transformations? Lavoisier, finding that oxygen is absorbed during acetification, concluded that its presence and absorption are indispensably necessary; that the oxygen enters into the composition of acetic acid; that acetic acid is alcohol *plus* oxygen; and that the change effected by the acetous fermentation is the oxidation of the alcohol. But the facts stated by Saussure tend to prove, that the oxygen absorbed during the acetous fermentation does not enter into combination with the alcohol; but acts the very different part of abstracting some of its carbon, combining with it, and thus forming carbonic acid, which then remains a separate compound, either exhaling or remaining mechanically mixed with the resulting liquor. Vauquelin conceived that the ferment takes both hydrogen and carbon from the alcohol, leaving therefore an increased ratio of oxygen, and thus converting it into acetic acid, while ammonia and an oily substance are formed; but the production of these two compounds seems not to have been ascertained.

Theories have also been brought forward to account for the formation of vinegar during the acetous fermentation, founded on the belief that the agency of the oxygen absorbed is to remove carbon and hydrogen from the alcohol, by the formation of carbonic acid and water; for it is known that acetic acid contains less carbon and hydrogen than alcohol. A theory of this kind, however, has to contend with the fact, that although oxygen is sometimes absorbed during the acetous fermentation, and carbonic acid formed, this absorption seems to be effected by some other carbonaceous matter present in the liquor, and not by the carbon of the alcohol: for, were this the case, the absorption of oxygen would be indispensable; *yet vinegar may be formed perfectly and with ease, even though the access of air be totally prevented.* This fact is proved by many instances. BECCHER included wine in a glass bottle, which it filled, and hermetically sealing the mouth, he exposed it to a digesting heat; after some time the wine was converted *into very strong vinegar.*

FOURCROY and VAUQUELIN obtained vinegar from a solution of sugar contained in close vessels. HOMBERG included good wine in a bottle, and, having closed it accurately, he fastened it to the sail of a wind-mill: in three days *it was very good vinegar.* It is a fact well known to every one, that a bottle filled with weak beer, and closely corked, will in some time be converted into vinegar. It may be said that air was absorbed through the cork; but this could scarcely happen, for after a cubic inch or two of oxygen would thus be absorbed, the neck of the bottle would be filled with nitrogen, and there being now no longer the aid of a partial vacuum, it is hard to conceive how air could enter. But the experiment of BECCHER seems to me irrefragable; and I think we are bound to admit, that the absorption of oxygen during the formation of vinegar is incidental, not necessary.—*Donovan.*

BECCHER states that the bottled wine was converted into very strong vinegar merely by exposing it to a digesting heat. The *strength* of the vinegar is not stated. It is well known that wine and other liquors include several cubic inches of atmospheric air, and it was no doubt the oxygen of this, aided by the heat, that produced the acetic acid. The wine must have contained upwards of twelve per cent. of alcohol; now vinegar containing two or three per cent. of acetic acid is considered good, and the Editor has no hesitation in saying, that there was sufficient oxygen in the wine used by BECCHER to produce vinegar of the above strength; therefore, this experiment does not at all do away with the opinion, that air or oxygen is necessary for the conversion of alcohol into acetic acid. The same reasoning will apply to HOMBERG'S experiment. The agitation his wine received on the sail of the windmill, would induce the combination of the alcohol with the oxygen contained in the liquid and that absorbed *through the cork.* Did not the wine in BECCHER and HOMBERG'S experiments contain a large quantity of spirit after being submitted to the agitation and digesting? If so, the deductions drawn by the Editor infallibly prove, that oxygen is necessary for the conversion of alcohol into acetic acid.

Vinegar is, according to the nature of the sources whence it is obtained, classed into several varieties. Of these the chief kinds are wine vinegar, sugar vinegar, malt vinegar, wood vinegar, and fruit vinegar, dependent, however, upon the presence of acetic acid as the first active principle, although they each possess a flavor and aroma peculiar to themselves; and on this account preference is given to some kinds of vinegars. All are produced by the acetous fermentation, except wood vinegar.

WINE VINEGAR.—*Weinessig*, German; *Vinaigre*, French.—This species of vinegar is chiefly fabricated in wine-growing localities, or where grapes are abundant, the principal factories being at Orleans in France. The building where the work is carried on is called a *vinaigrerie*, and has always a southern aspect. The casks, called *mothers*, which are employed, hold from fifty to one hundred gallons, and rest upon strong wooden frames, supported by pillars of wood or stone of eighteen inches in height. Several such casks are placed in rows, and when acetification is carried on in the open air, eight, ten, fifteen, or twenty such ranks constitute what is termed a *vinegar-field.* Two holes are bored in the upper surface of the front end of each cask; the larger serves to charge the cask with wine, as also to draw off the vinegar when formed, and the smaller allows an influx or efflux of air as the cask is emptied or charged. The chief aim of the person who wishes to carry on a vinegar factory, is to have a good fermenting-room, where the wines are exposed to an even temperature, having a copious supply of atmospheric air and moderate ventilation—the air-holes for this purpose being constructed so as to admit of being closed in windy weather, or when the temperature of the room is depressed. The walls of the apartments are of brick, or such non-conducting material, and lined with lath and plaster.

Low-roofed apartments are the most suitable; when there is a high ceiling it is necessary to elevate the mothers, in order that they may occupy the higher strata of warm air—this trouble is dispensed with when the roofs are low. Experience has pointed out, that in high-roofed apartments, where the tuns are placed at different levels, the uppermost work off quicker and better than the others. In the event of new mothers or vessels being used, it is needful to fill them one-third full with the strongest vinegar at a boiling temperature. This forms the stock, or true *mother;* the charges of wine added each time are two and a half gallons to every cask, and an interval of eight days is allowed for the acetification of each charge, before adding another of fresh wine. This treatment is continued—of charging, and allowing eight days to work it off—till the casks are more than half full. One-third of the contents of each mother is then siphoned off—in some factories only ten gallons—and run into the store tuns, and the process repeated anew of charging every eight days till the mothers are refilled, as before. Some manufacturers do not suffer the vinegar to remain in the mothers till they are two-thirds full, but siphon off, at the end of every sixth or eighth charge, twelve or fifteen gallons of vinegar. The mothers should never be charged with more than the above quantity, in order to carry on a steady and efficient mode of acetification. Occasionally it happens that eight days are not sufficient to finish every charge; this is more unaccountable from the fact, that the backward casks receive the same amount of care, and have the same temperature, as those which work well. It often occurs that the casks in the warmest part of the room are those which are backward, or *lazy*, as they are termed. In this event, nothing remains but to empty such mothers of their contents and fill them with hot strong vinegar, when, on adding fresh charges, the acetous fermentation recommences, and goes on as briskly as in the rest. Sometimes fresh quantities of a stronger wine, and an increase of temperature, are supplied, to quicken the fermentation in such casks—which mode is often successful: the *laziness* of the mothers is attributed to very vague and unsatisfactory causes, some regarding it as the effect of the electrical state of the casks and liquid.

It has been recommended to isolate the mothers as much as possible, and to use little or no iron in the construction of the casks. To ascertain if the liquor has fermented, the following experiment is resorted to. A white rod, bent at one end, is plunged into the mothers, and drawn out in a horizontal direction; if the rod be covered with a thick white froth—flowers of vinegar—the operation is said to be terminated; if the froth be reddish-brown more wine is added, and the temperature increased till the whole is acetified. In summer the natural heat is sufficient, but in winter the mothers are heated, by means of a stove, to about 80° Fahr. The prevailing temperature should range between 75° and 80° Fahr. When proper attention has been paid to the manufacture, the mothers usually work off double their contents of vinegar annually. The precipitation of the insoluble matters of ferment, the accumulation of *mother of vinegar*, and the deposit of tartar from the wine, fill the casks to such an extent that it is indispensable to empty the whole of them, and free them from these deposits every six or eight years—and often the entire factory needs renovation, as was the case with a malt vinegar one in Liverpool, which the Editor recently inspected; but good casks will last for a period of twenty-five years. The wine, if it be ropy, is introduced into a large tun filled with beechwood shavings, through a funnel opening in the cover, and allowed to repose for some time, whence it is afterwards drawn off by a tap in the lower part of the tun, and supplied to the mothers as required. Frequently, when weak wines are employed, from the proportionably large amount of vegetal matter they contain, it happens that the resulting vinegar is ropy and turbid; in these instances, it is necessary to pass it through the clarifying or *fining* tun, and the advantage of having an average vinegar is gained.

The old method, introduced by BOERHAAVE, is still practised in Holland, in France, and on the Rhine. Two large tuns or vats, about nine feet high and four feet in diameter, are supported on stands, about twelve inches from the floor. Within one foot from the bottom of each vat is a perforated bottom or wooden grate, resembling that of a riddle; on this a quantity of fresh cuttings from the vine, willow twigs, *et cetera*, is placed, and pressed closely together, the remainder of the vats being filled with *rapes*—the footstalks of the grapes—and other light branches. Both vats are left open for the admission of the extrinsic air. They are then charged with wine; one is completely filled, the other only half. The two are left at rest for twenty-four hours at 75° Fahr., after which the half-filled vat is replenished from that already full, till the latter contains only half its contents of liquor; twenty-four hours elapse before the liquid is retransferred from the filled to the half-filled vat.

The process of transferring the liquid into the vats alternately, is repeated every twenty-four hours until the vinegar is made. Towards the third or fourth day an internal effervescence is observed in the half-filled vat, which is accompanied by a sensible elevation of temperature, increasing gradually each successive day. On the other hand, the temperature and fermenting action of the filled vat are but sluggishly progressing, so that the intestine motion takes place only on alternate days in each vat. The completion of the process is known by the decreased temperature and abated action even in the half-filled vat. The vinegar is then drawn off into casks, and left in a cool situation till it clarifies. During summer, the time occupied is fifteen days; but in winter the acetification extends over a longer period. The temperature of the half-empty vat should never exceed 80° Fahr.; if it rises to 84°, the liquor is to be transferred every twelve hours, and an oaken cover placed on the half-filled vat in order to check the fermentation, otherwise the aldehyde, or half-made vinegar, will be dissipated, and only a vapid fluid remains, sour, but effete. If the whole be kept at 83°, and the menstruum transferred every twelve hours, the acetification will be effected in eight or ten days. According to DUMAS, the best French vinegar is made of good wine, which is put into a cask already containing vinegar, and to which atmospheric air has constant access. As acetification proceeds, more wine is added at intervals, and when the whole has become vinegar, it is drawn off to the amount of the wine used, and the process is repeated. Its strength, flavor, and color, depend upon the characters of the wine employed. The temperature of the factory is maintained at 86°.

MULDER, the celebrated chemist of Utrecht, has given a very interesting account of the vinegar mother or ferment — *Mycoderma aceti* — which the Editor appends:—It is self-evident, says MULDER, that the origin of organized beings from non-organized substances, must depend upon a transmutation. Researches for the purpose of explaining this point must evidently proceed from the most simple case: such a case is the formation of the so-called vinegar mother, a plant originating in the vinegar, and, in fact, at the expense of its constituents. This cryptogamous vegetal may justly be regarded as one of the most simple vegetal formations, and belongs rather to the Fungi than to the Algæ. Fruit-bearing organs, with globular sporidia, could never be detected in this species which grows in the vinegar—*Mycoderma vini* and *Mycoderma cerevisiæ*, which probably constitute one species. It does not originate in wood vinegar, but always in wine and beer vinegars, causing whole vats of it to pass into water. The vinegar mother is also often found in vinegar in which organic substances have been preserved; however, these substances contribute nothing to the development of the mould plant, they only further the origin of a germ, a cell, which separates from the mass, and now, as a germ, forms a plant from the elements of the acetic acid.

From wine vinegar, in which totally different substances have been preserved, the very same species of *Mycoderma* was developed, the same organized structure, the same mould plant, identical in form and in chemical composition.

The principal constituents of the wine vinegars are, acetic acid, $C_4 H_3 O_3$, and water, $H O$. They contain also some salts, a small quantity of sugar, gum, and extractive substance, and, above all, some protein, derived from the albumen of the grapes, dissolved in the acetic acid. In vinegar in which vegetal substances —for instance, gherkins, cherries, *et cetera*—have been preserved, the quantity of the protein may be increased from these vegetals; but that this is not requisite, is evident from the formation of the vinegar mother in pure wine or beer vinegar. The aliments of this vegetal mould are, therefore, $C_4 H_3 O_3$, $H O$, and $C_{40} H_{31} N_5 O_{12}$.

Now, these constituents are found to be grouped in a very simple manner in the plant, while both protein and acetic acid disappear from the liquid; moreover, the plant contains nothing else, and we are, therefore, able to follow chemically the transformation of acetic acid and protein into a plant.

It is not less remarkable, that the plant has always the same chemical composition; and the organization, consequently, requires a definite proportion of acetic acid and protein, the latter of which remains unaltered, while the former yields a cellular substance under absorption of water. The new product of the acetic acid combines in atomic proportions, just as well as the formation of gypsum from carbonate of lime and sulphuric acid.

The vegetal mould examined by Mulder was taken from vinegar in which some substances had been kept. Although always wine vinegar, the samples were of various origin, and had preserved the following:—

No. I.,	Currants.
No. II.,	Cucumbers.
No. III.,	Gherkins.

In the last it formed very rapidly. The first traces of it were observed five days after placing the substances in the vinegar; on removing the first crust, the second formed in the course of a week, and so on for the five subsequent weeks, always a new one, although the vessel was well closed. The strength of the acetic acid decreased more and more, until, at last, only water remained: all these crusts had the same properties. The species of *Mycoderma* examined, always formed a coriaceous membrane, more or less elastic, saturated with vinegar, and of a white color, except that from the vinegar of the currants, which was reddish. By kneading and pressing, the membrane becomes void of taste and smell. Neither water nor alcohol dissolves anything from it by boiling. On incineration, it does not leave the slightest trace of ash; submitted to destructive distillation it affords much carbon, and an acid liquid distils over, from which potassa liberates ammonia. It is not altered by cold strong sulphuric acid; but in the heat it becomes first red, then, under decomposition of the sulphuric acid, brown, and lastly, black. Concentrated nitric acid colors it yellow, and on the application of heat it dissolves very slowly in it; hydro chloric acid has no sensible action upon it; strong acetic acid takes up, when boiled with it, some protein, the presence of which can be demonstrated by ferrocyanide of potassium.

When well purified with water and alcohol, it ceases to lose any more weight at from 248° to 275° Fahr. The analysis of the three kinds gave:—

	I.	II.	III.	Theory.
Carbon,	46·75	46·89	46·89	46·60
Hydrogen,	6·51	6·52	6·50	6·40
Nitrogen,	—	—	3·87	3·96
Oxygen,	—	—	42·74	43·04
			100·00	100·00

By long digestion with potassa, and continued boiling with acetic acid, the whole of the protein may be extracted, leaving pure cellulose, which is not combined with any other body. This cellulose, which was examined by Payen and others, has the formula, $C_{24} H_{21} O_{21}$, or that of the solid modification of inulin, which Rosé obtained as a white precipitate during the cooling of a strong decoction of elecampane root. Payen procured it from the grated root of the dahlia.

By following the mode of formation of the plant from the vinegar, the first thing observed is, that the protein which was present in the vinegar as albumen from the grape, passes from the dissolved state into a solid, synchronously, assuming an organic form. On employing wood vinegar, the protein must be furnished by the vegetal substances which had been preserved in it; but, as above stated, pure wine vinegar also produces vinegar mother; the cellulose, therefore, can have originated solely from the acetic acid.

$$\underbrace{C_4\, H_3\, O_3}_{\text{Acetic acid.}} \times 6 + 3\, H\, O = \underbrace{C_{24}\, H_{21}\, O_{21}}_{\text{Cellulose.}}.$$

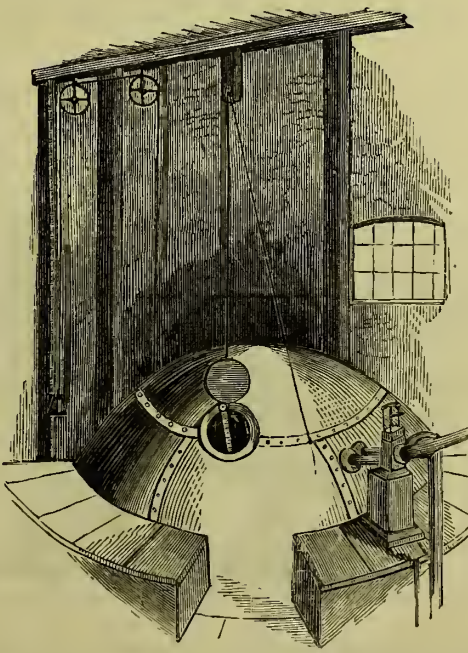
MALT VINEGAR.—*Malz-Getreide-oder-Bieressig*, German.—In this country, the chief part of the vinegar is made from *malt wash*, or *gyle*, prepared by operating upon the materials in the annexed proportions:—Six bushels of good barley malt, properly ground, are mashed with forty gallons of water at 160° Fahr., permitted to repose till the solid matter settles down, the solution drawn off, and the residue affused with a fresh quantity of water, say forty gallons, at 180°, well agitated for a short time, allowed to settle, then siphoned off as before; and to take up all the soluble matters, the third washings may be performed with boiling water. On the whole, not more than one hundred gallons of wash is to be used in extracting the soluble matters. When the solution has cooled to about 75°, it is well agitated with four gallons of yeast of beer; and after thirty-six or forty hours, raked off into casks, and placed in the vinegar stoves or apartments, the temperature of which should range from 70° to 77° Fahr. The casks should be placed on their sides, the bungholes opened, and a circulation of air kept up in each cask by means of an orifice bored at each end of the cask, near its upper edge. Since the temperature of the liquid is somewhat less than the surrounding atmosphere, in consequence of the evaporation at the surface, an efflux of cold air takes place at the holes while the warm air enters at the bung, and thus a constant current is kept up. Frequently this manufacture is effected by *fielding:* the casks rest on strong frames, one foot and a half high, being supported by firm pillars of brickwork or wood. Six or eight rows of these are arranged parallel to each other, with a narrow walk between each pair of rows; a sluice is placed along the casks into which the vinegar is siphoned, whence it flows into the store tuns in the magazine; and a flexible tube, or hose, supplies the *wash* from the great tun in the brewhouse. The bungholes are left open in dry, and are loosely covered with a tile in rainy weather. One-third of each *mother* is left empty for the circulation of air, so as to oxidize the alcohol as it generates in the wort. Three months are required to complete the process, and render the vinegar marketable.

What constitutes malt is generally known, but it may be stated here, that the process of malting changes the character of the grain, by converting some of the starch contained in the barley into sugar, and facilitating the similar conversion of a further portion. This conversion into sugar, called the *saccharine fermentation*, is one of the important steps in the preparation of beer, whisky, and malt vinegar: in all of these it is requisite that the starch of the grain be converted into a kind of sugar, for it is from this that the vinous fermentation produces alcohol, the parent of vinegar. Hence the early processes in an ale brewery, a malt distillery, and a malt vinegar works, are similar.

In the factory about to be described, the malt is hauled up out of the waggons into the upper floors of the brewhouse. Here openings, placed in different directions, permit of the malt being poured down into large bins, whence it is removed when a brewing is going to commence. Vinegar-makers and distillers, as well as beer-brewers, give the name of *brewing* to the extraction of a saccharine liquor from malt. The quantity required for one brewing being measured out, and taken from the bins in sacks, it is poured through *hoppers*, or funnels, at the top of the grinding apparatus, whereby the malt is reduced to meal. The apparatus consists of both the kinds used for such purposes, *videlicet*, millstones and crushing-rollers, either or both of which can be employed as may be deemed advisable. In the one case, a flat circular stone rotates and crushes beneath it the malt, which flows between it and a lower fixed stone: in the other, the malt, after flowing through a shoot or trunk from the hopper, falls on a wire grating, where it becomes depurated. It then passes between two cast-iron rollers, rotating nearly in contact, by which means it is crushed into fragments. An ingenious contrivance, says DODD, invented by Captain HUDDART, is adopted for yielding to any hard substance which may enter between the rollers and the malt, without injury to the apparatus; it acts on the principle of stopping the circular motion of the rollers altogether, until the cause of hindrance is removed.

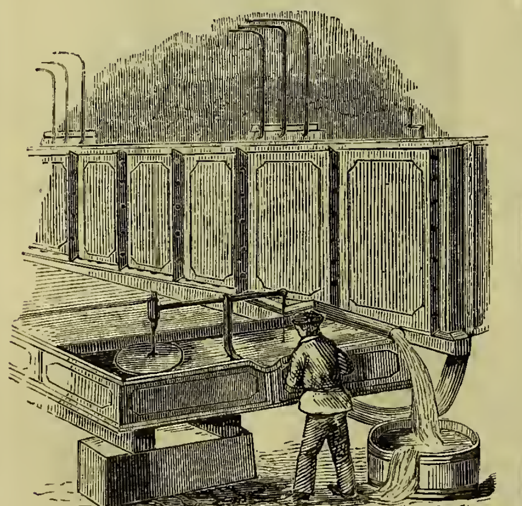
When the malt is crushed or ground, it falls through a hose or trunk into the mash-tuns in the floor beneath. These mash-tuns are similar to those used at large breweries and distilleries, but smaller in size. They are circular vessels, with a central *stirrer*, or instrument for keeping in constant agitation the ingredients contained in the tuns—the stirrer being worked by a steam-engine. It is in these vessels that the *saccharine fermentation* proceeds, or the extraction, by the action of hot water, of a sweet or mawkish substance from the malt. This is the sweet principle which subsequently yields to the brewer, his beer; to the distiller, his spirit; and to the vinegar-maker, his acetic acid: and it may well be supposed, that every precaution is taken, and every investigation made, as to the extraction of the greatest quantity, and the most fitting quality, of this important agent. The quantity of water required for a given quantity of malt, and the temperature at which the water is used, vary in each particular branch of manufacture, according to the strength of the *wort* required. The arrangements for settling these are very exact and ingenious. Hot water is let down upon the malt in the mash-tun, when at the proper temperature; and in order to adjust this, the foreman of the brewhouse ascertains, by the aid of a thermometer, the temperature of the water through a temporary opening in the upper part of the boiler. This is shown in Fig. 4, where is also represented a balance-weight and graduated scale, which, aided by a float on the surface of the liquid in the copper, indicates the depth of the water.

Fig. 4.



When the water has acted on the malt for a certain period, and been constantly stirred with it, the liquor receives the name of *wort*, and is allowed to flow through pipes out of the mash-tuns into a large cast-iron tank, or *underback*, measuring twenty-four feet or upwards in length, by eight in width. This is merely a general receptacle for the wort, into which the latter is collected when the mashing is completed. Then ensues the process of *cooling*, one which exhibits many remarkable differences, as effected in different establishments. Large, open, shallow, airy rooms, called *coolers*, or *cooling-floors*, whereon the wort was poured in a thin layer, to be cooled by the access of air on all sides, was formerly the mode adopted at the vinegar works now under description; a surface of nearly twenty-three hundred square feet having been appropriated to this purpose. This mode has, however, been superseded by another, in which one hundred square feet of surface is made to yield the effects formerly wrought by more than twenty times that extent. There is a vessel now employed for this purpose, called a *refrigerator*, which acts on the following principle:—The hot wort is allowed to flow out of the underback into an oblong vessel, and out of this into another receptacle in the same part of the building. A continuous pipe, between three and four hundred feet in length, passes backwards and forwards through the oblong vessel, and through this pipe cold water flows incessantly, from an Artesian well two hundred feet in depth. Constant currents of wort run in one direction through the apparatus, while a current of water in an opposite direction flows through the pipe which cools the wort.

Fig. 5.



The temperature of the wort may be cooled even to that of the water were it required, either by increasing its influx and retarding its efflux, or by permitting a larger quantity of water to flow through the pipe. The heat of the wort is abstracted by the colder medium with which it is in contact, so that the liquid becomes colder as it passes to the exit pipe till the proper temperature is attained—the flow of wort and water being regulated by suitably adjusted valves, which admit of the proper quantity of each liquid. Fig. 5 represents the refrigerator at the end where the wort enters, and where the water leaves the pipe, after having performed its office; collateral with the refrigerator is the underback. Not only does this method require much less room than that of the cooling-floor, but the refrigeration is greatly accelerated, and the manufacturer is rendered independent of the fluctuations of the weather; for his refrigerating agent being brought from a source two hundred feet below the level of the ground, has, summer and winter, nearly the same temperature.

The reader must bear in mind, that the wort produced is precisely the same as that made by the beer-brewer and the distiller, differing solely in saccharine strength. It suffers likewise the same process of fermentation, subject, of course, to any limitations that may be required by its nature. From the refrigerator, the cooled wort flows into the *jack-back*, a large circular receptacle sunk in the ground, whence it is pumped up into fermenting tuns. A valuable system of combination or centralization is observable in the arrangement of the conducting pipes.

Large vessels are clustered, serving as a kind of common centre, from each of which openings lead to several other vessels, each orifice being regulated by a particular valve; for example, the liquid which, in various processes, is contained in the jack-back, has sometimes to be transferred to the fermenting tuns, at one time or other to a large back or cistern at the top of the building, and oftentimes to the copper; still there are not *three* openings from the jack-back for these several purposes, but *one*, which leads to a three-barreled pump, the barrels of which are respectively marked *tuns, back, copper;* so that, by turning one of three handles, the liquid can be conveyed to either one of these. Again, the back just alluded to is placed in connection with several other large tuns or backs, in different parts of the premises, to any one of which its contents can be transferred by simply turning a handle. An hexagonal table is in one of the buildings, under the surface of which are six valves, all opened and shut by one key. On each tap the name of some particular vessel or building is inscribed, with which it is in adunation by an extensive series of subjacent pipes; and the overseer of this small piece of apparatus can control, in almost any direction, the flow of the liquid under manufacture. Such a system of classification is excellent.

The *gyle* is transferred from the fermenting tuns to other large casks, where it deposits, in course, a kind of acetous yeast—mother of vinegar; and being thence permitted to flow into the jack-back, it is drawn up one of the branches of the three-barreled pump into the large vat at the top; from this, as a centre, the gyle is allowed to flow into casks, where, after a longer or shorter period, it assumes the form of vinegar.

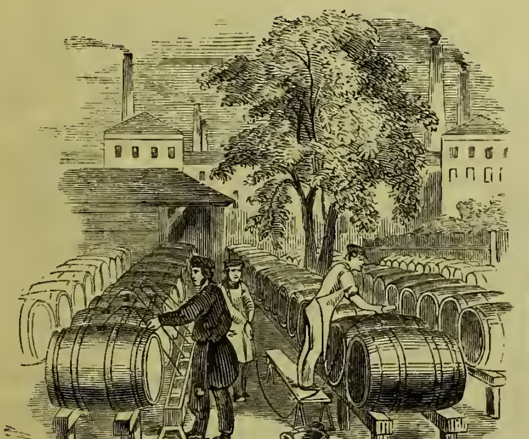
Transformation of the fermented wort into vinegar is effected at the factory in two ways, which are entirely opposite in their manner of operation. In the one case, the casks containing the gyle are placed in close rooms, heated to a high temperature; in the other, they are ranged in rows in an open field, where they remain many months. Different as these methods seem to be, yet the effect produced is precisely the same; *videlicet*, the conversion of the gyle into vinegar, by the process of acetification. As regards the convenience and interests of the manufacturer, both methods seem to have their several advantages; for at the vinegar works under consideration, both are followed, although one occupies a very much longer period of time than the other.

When *fielding* is resorted to, it must be made during the spring months, and then left to finish during several months in the warmth of the season. Technically, the other process is called *stoving*, and in this case the casks containing the gyle are arranged conveniently in three stove-rooms, which are closed and locked, and then exposed to a certain temperature till the acetification is concluded. A cursory visit to one of these apartments readily convinces us of the progress of the fabrication, by the pungent acetous odor of its atmosphere.

The fielding method requires a much larger extent of space, and other utensils, than the stoving, from the peculiarities always attendant upon it.

The casks, as already described, are placed in several lengthy parallel tiers, with their bung-side upwards, and left open. Beneath some of the paths which separate the rows of casks, are pipes, communicating with the back at the top of the brewhouse; and in the centre of each of these paths is a valve, or opening into the concealed pipe. When the casks are about to be filled, a flexible hose is screwed on to this valvular opening, the other end of the hose being inserted into the bung-hole of the cask, and the liquor in the gyle-back at the brewhouse, by its hydrostatic pressure, flows through the underlying pipe and hose into the cask. The hose is so long as to admit of reaching to all the casks in the same row, from the valve, and is guided by a workman, as is seen in Fig. 6. After due time the vinegar is made, and is drawn off by the following ingenious operation. A long trough or sluice is laid by the side of one of the rows of casks, into which the vinegar is transferred by means of a siphon, whose shorter limb is inserted in the bung-hole of the cask. The trough inclines a little from one end to the other, and its lower end rests on a kind of traveling tank or cistern, wherein the vinegar from several casks is collected. A hose descends from the tank to the open valve of an underground pipe, that terminates in one of the buildings or stores; and by the agency of a steam-boiler and machinery in the adjacent buildings, the pipe is exhausted of its air, and this causes the vinegar to flow through the hose into the valve of the pipe, and thence into the factory buildings. By this arrangement the whole of the vinegar is drawn off, and, as if it were, invisibly. This arrangement is partly seen in the engraving. From the storehouse where the vinegar is received, it is pumped into the *refining* or *rape* vessels, and filtered, to separate mucilaginous matter. These vessels are often filled with wood shavings, straw, or spent tanners' wood, but none of them acts as a substitute for the stalks and skins of the grapes—rapes—in producing by filtration a bright vinegar.

Fig. 6.



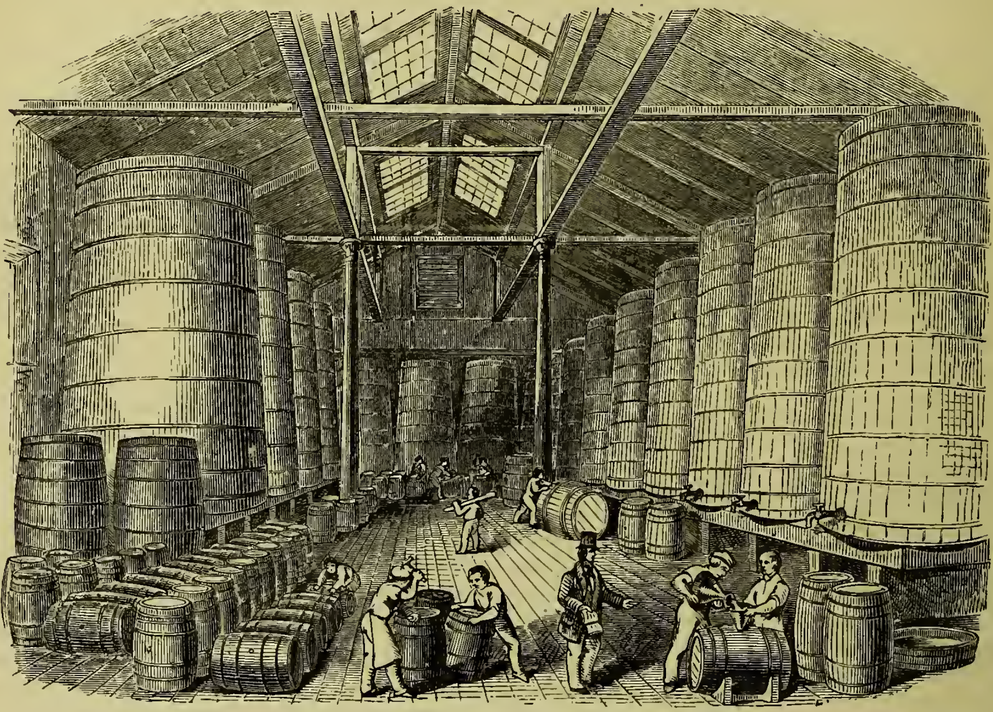
It is a matter of difficulty to collect a proper stock of rapes, to supply a filtering medium for a large vinegar work, when several huge refiners are in operation; and, when once collected, no part of the materials relating to the factory are treasured with so much care.

Dodd describes each rape or filtering vessel as being fitted with a false bottom, on which the grape stalks are placed. Beneath this false bottom, and above the true one, a tap is inserted, which allows the vinegar to flow into a back or cistern. From this cistern a pump elevates the liquid to the top of the vessel, and hence ensues a very curious circuit: the vessel is filled with vinegar, which filters through the raisin-refuse into the space beneath, from there into the tank, thence through the pump to the top of the vessel, to recommence its circuit. Over and over does this circuit proceed, the pump being kept constantly at work, and the vinegar incessantly in motion. If such a comparison might be permitted, we would liken the pump to a heart, which propels the liquid to the enormous lung—the rape—where it is depurated, and then again returned to the heart. The filtering substance gradually, but very slowly, wastes away, but is renewed from time to time.

Vinegar, by this process, becomes transparent, or *bright*, as it is technically termed, and is then pumped from the rapes into store-vats, where it is kept till required to be put into casks for sale; and the rapes are immediately filled up with an equivalent portion of fresh vinegar, so as never to leave the raisin-refuse idle. The vinegar casks hold one hundred and sixteen, fifty, and twenty-five gallons, respectively. Each cask is examined and gaged before being brought into the *sending-out warehouse*, to see that it is sound and of proper dimensions. The warehouse is a large room, lined on all sides by store-vats, from which the casks are filled; and on the days when these casks are to be despatched, a very busy scene is presented with coopers, porters, *et cetera*, ranging the casks, marking them, and consigning them to the waggons.—See Fig. 7.

Vinegar for household purposes is made in the following manner:—The malt being prepared in the usual way, a quantity of *argol*—winestone—is added, and afterwards introduced into the casks. The casks have a perforated bottom, about a foot above the true one, and are placed on their end. A quantity of refuse of raisins, from wine factories, is placed on the false bottom, and the wash at the temperature of 70°—a proper addition of yeast being previously made—is poured upon the rapes in the casks. After twenty-four hours the wash is racked off into another cask of the same description, and allowed to remain in this for a day or two, when it is drawn off into a third and fourth cask. The liquid, after spending twenty-four hours in the last cask, is raked off and supplied to the mothers; then allowed to ferment quietly, as in the preceding instances, at a temperature of 70° Fahr. Argol communicates to it the appearance of wine vinegar. It is clarified by leaving it in the casks, for some time, with a little isinglass.

Fig. 7



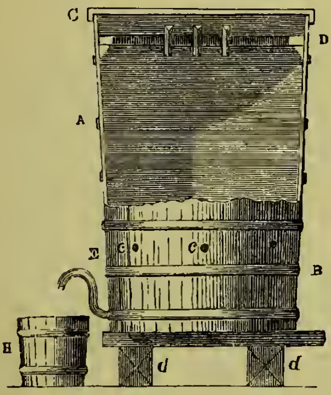
SUGAR AND CIDER VINEGAR.—In many factories, instead of a sweet wort of malt, a solution of sugar is often employed to produce vinegar. Several receipts are given for this department of the manufacture, the principal being the annexed:—Dissolve ten pounds of sugar and six pounds of winestone in forty gallons of boiling water; put the solution into the fermenting tun, and when cooled down to 80°, add four quarts of beer yeast, and agitate the whole thoroughly. Grant the liquid repose for six or eight days, at a temperature of 75°, till the vinous fermentation is ended; after which rake it off, and submit the liquor to the acetous fermentation, either by one or other of the modes already mentioned, or by the *graduator* process, which will be presently described. Another prescription is—

100 parts of water,	or	120 parts of water,
13 parts of brandy,		12 parts of brandy,
4 parts of honey,		3 parts of brown sugar, and
1 part of tartar,		1 part of tartar,

—surrendered to the usual processes till the acetous fermentation is fulfilled.

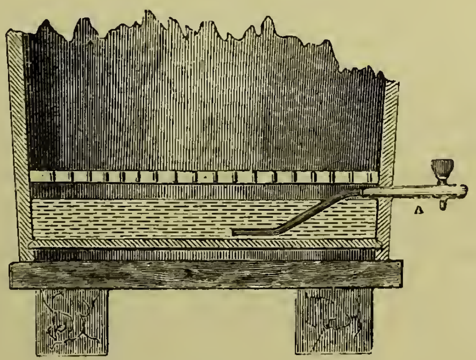
QUICK VINEGAR PROCESS.—*Schnellessigbereitung*, German.—From the length of time necessarily occupied in making vinegar, as hitherto described, the name of *slow vinegar process* has been given to the manufacture since the application of a quicker method for accomplishing the same end. Of the older methods, the only approximation to the process now considered, was that of BOERHAAVE, described under Wine Vinegar, at page 7. Mr. HAM of Bristol patented, some thirty years ago, a process very closely resembling the *graduator*, but much inferior, inasmuch as the surface exposed to active oxidation was far less in the former than in the latter. Good vinegar is at present made from alcoholic liquors, in the course of thirty-six to forty-eight hours. The slow and quick processes are conducted upon the same principle, namely, the oxidation of the alcohol; but the manner in which it is oxidized is different—the surface exposed in the quick method being many thousand times more extensive than in any former one. Before entering minutely into the arrangement of the vessels employed, it will be as well to state curtly, that an extreme division of the liquor is effected, as when it comes into play it can only percolate very slowly, and thus diffusing itself over shavings, forms a very thin liquid layer, the surface of which is exceedingly large, and is therefore better adapted for the chemical appropriation of the oxygen in the current of air which is transmitted over it. A gallon of liquor, when subjected to the quick method of acetification, if allowed to percolate slowly, offers a surface of about one hundred square yards to the action of the air during its descent.

Fig. 8.



The graduator, which Fig. 8 represents, is a large tub or tun, A, of oak, eight feet high, three and a half feet diameter at bottom, and four feet at the top, and rests upon a stage, *d d*, of wood or brickwork, one foot and a half high. A stout hoop of beechwood is fastened in the interior of the tub at B, eighteen inches from the bottom, and a perforated shelf placed thereon; and two inches above this, eight or ten holes, *c c*, one to one and a half inch diameter, are bored, equidistant round the cask, and inclining downwards from the outside. Another strong beechwood hoop, D, is fixed a foot from the top of the tub, on which is placed a second perforated cover, fitting the interior of the vessel tightly —the holes being one inch apart, and one-fourth of an inch in diameter. These apertures are loosely filled with cotton wick or packthread, a knot being made at the top end to keep them from falling through the cover; they pass down to the shavings, and serve the purpose of conducting the liquor equally through the body of the tub, as likewise to arrest it from passing too rapidly through the tun. The space between the bottom and top shelves is filled with shavings of beechwood, and a thermometer is introduced a little below the top cover, the bulb of which reaches the middle of the apparatus, to indicate the rise or fall of temperature, as the subsequent oxidation of the alcohol is greater or less. Six larger holes are bored in the upper cover, one and a half inch in diameter, into which wooden or glass tubes, opening below it, and about nine inches long, are adjusted; these serve as chimneys to carry off the deoxidized air from the vessel. A loose oaken cover, C, with a funnel opening in the centre, through which the liquids for charging the graduator are supplied, protects the whole from dust, *et cetera.* At one and a half or two inches from the bottom of the graduator, a pipe or glass tube, E, is inserted; it bends upwards nearly as high as the lower perforated shelf, and then curves extrinsically, so as to discharge the liquid into an appropriate vessel, H, placed beneath it, when it rises so high as the shelf in the interior of the vessel. A wooden pipe, twelve or fifteen inches long, is fixed in the lower part of the vessel—see Fig. 9 —having a plug or wooden screw fitting the bore of the pipe, that acts as a tap, by which the dregs and other albuminous matters that accumulate are run off. Everything being thus arranged, hot strong vinegar is poured through the funnel opening in the outer cover, and passed through the graduator for one or two days, to induce an eremacausis or slow combustion of the shavings and sides of the graduator, before passing the fresh spirituous liquors through for acetification. To fill the tun, a standard liquor is taken, consisting of fifty gallons of brandy or whisky, of sixty per cent. by volume, and thirty-seven gallons of beer or malt wort. Acetification takes place slowly in the beginning; but when the shavings become gradually impregnated with mother of vinegar, the oxidation is accelerated, and the larger the amount of this body the quicker the oxidation; so that the process goes on improving. Sometimes five gallons of the above liquor are mixed with forty to fifty gallons of weak vinegar, and passed through the vessel at a temperature of 80° Fahr., and by this means the alcohol is more readily oxidized. It is well known that essential oils, or a mere trace of wood vinegar, arrest acetifying; consequently, the vinegar used must be free from pyroligneous acid. The tun, or graduator, being thus brought into a proper state of working, fifteen to twenty gallons of the standard liquor previously mentioned, are diluted with sixty gallons of soft water, and poured into the tun through the funnel in the outer cover, and permitted to pass through; it is again returned to it, unless there be several graduators in the factory, and in that case the liquor, after passing through the first, is allowed to percolate the second tub. Every succeeding hour, two and a half gallons are drawn off from the second tub, that of the first being kept as vinegar, while the

Fig. 9.



product of the second is always returned to the first vat or graduator; thus, in twenty-four hours, thirty gallons of vinegar are ready for sale. One hundred and fifty gallons of superior vinegar can be manufactured daily in ten tuns, which one man can superintend. From the purity and clearness of the product, it resembles distilled vinegar; but to make it more marketable, one pound of cream of tartar, and two pounds of brown sugar or molasses, may be added to every fifty gallons, to suit the palate of the buyers. If honey or molasses be previously added to the spirituous liquor, a vinegar of a good color is at once obtained: this addition is often made for the sake of economy. The temperature of the rooms should be at 100° Fahr., and that of the standard liquor 125° to 130° when poured in. After the working tuns have acquired a proper state for the acetification of the liquid, a temperature of 70° should be kept up in the apartments, and the charging liquid at 78° or 80°. During the time the solution is percolating, the temperature of the graduator rises to 100°—108°, from the rapid oxidation of the alcohol, as will be indicated by the thermometer as long as the operation goes on favorably. If a stronger acid be required than the product of the first and second vessels, the mode adopted is to mix the vinegar made in the first and second tuns, with a stronger alcoholic liquor, and pass the mixture through a third tub; and if, when transmitted, it should be required still stronger, a fresh quantity of alcohol is added, and submitted to a fourth tub, to obtain acid of the strength required. The vinegar procured in this way, from the first and second tuns, will require thirty to thirty-six grains of pure carbonate of potassa to neutralize every fluid ounce; that from the third tub, after being mixed with twenty gallons of the standard liquor, instead of sixteen or eighteen, will neutralize forty-five grains, and that from the fourth graduator may be made of that strength, that an ounce will saturate fifty to sixty grains of the pure alkaline carbonate.

When thick muddy liquors, or those containing much organic substance, as beers, or other mucilaginous matters, are filtered through the tuns, their dregs deposit on the chips, the accumulation of which prevents the liquid from percolating, and consequently the further oxidation of the alcohol is arrested. Should this happen, the chips are withdrawn from the graduator, washed with hot water, then steeped in hot strong vinegar, as in the forementioned instance, and returned to the tub; or a stream of hot water may be made to pass through without taking out the shavings, and afterwards hot strong vinegar, as before stated. It is better, however, always to use liquors free from sedimentary or slimy matters to charge the tuns; and if there should be any such, they ought to remain for some time in the clarifying vessel before submitting them to acetification: when these precautions are observed, the tuns will not so soon require cleansing, and the products will be purer and better. Many employ pieces of charcoal, about the size of a walnut, which have been deprived of their saline ingredients by dilute hydrochloric acid, and afterwards, of the acid, by water. The charcoal effects the oxidation of the spirit much quicker than the shavings, and it does not become so quickly choked with mother of vinegar. All those liquors spoken of in describing the *slow processes*, and indeed all alcoholic liquors free from empyreumatic products, are converted into vinegar by this method. The *wine malt* for charging the graduators is made from wheat and barley malt, mixed in the proportion of forty pounds of the former to eighty pounds of the latter; the whole well ground and saturated with forty gallons of water at 120° Fahr. After the subsidence of the solid parts, the clear supernatant liquor is drawn off, and the residuary matter washed with water at 160°, agitated, and drawn off as before; and a third affusion, in order to extract all soluble matters, is made at 200°—212° Fahr.; the whole of the washings should not exceed one hundred and ten gallons. The solution is cooled to 75°, and fifteen pounds of yeast are well comminuted with it, the whole left at rest in an atmosphere of 80° for five or six days, to undergo the vinous fermentation, after the termination of which it is ready for the graduators. Although this method is seemingly the perfection of rapid acetification in the vinegar manufacture, yet, without proper care, it is subject to its losses. In the slow methods, from the lengthy exposure to the atmosphere, a vast quantity of vinegar is evaporated and lost, even at a low temperature; much more will the elevated temperature of the graduators expel the half-converted alcohol—aldehyde—and it may happen that not a trace of acetic acid remains after the termination of the process. In the first application of the *quick* modification, this loss was very much felt, owing to the escape of aldehyde, then unknown; but on its being discovered, the chemist at once saw that the cause of the deficiency was the imperfect oxidation of this compound; and to remedy the evil, he advised an increase in the holes in the graduator, so as to admit a larger supply of atmospheric air, which proved successful. This is one of the thousands of instances of the advantages to be derived by the manufacturer having a knowledge of chemistry; and, moreover, is a happy illustration of the value of theoretic knowledge, when properly applied; for every apparently useless discovery of the theorist may, at some time or other, be made available to the perfection of the arts. The formula at page 4, expresses the change that takes place in the graduator. The formation of aldehyde may be shown by closing some of the openings which serve to supply air to the tun, and when the alcoholic liquor has passed through, by applying a solution of strong potassa to a portion of the clear liquid, we invariably obtain a brownish precipitate—aldehyde resin—which is characteristic of this body; and further, if the solution be boiled in a test tube with a little oxide of silver, decomposition ensues; part of the oxide of silver is reduced to metal, which forms a coating on the glass, and the aldehyde is converted, by uniting with the oxygen of the reduced silver, into *aldehydic* or *lampic* acid, which unites with the remaining oxide of silver, forming a soluble salt. Aldehyde boils at 70°, and at 65° its spec. grav. is 0·79; it has a peculiar ethereal odor, and is inflammable. These facts will serve to guide the manufacturer in regulating the proper circulation of air in the tuns, taking care, however, that there is not a superabundant supply, by which alcohol would be lost, from the increased temperature—110° to 120° Fahr.,—consequent on the too rapid oxidation of the spiritous liquids. Theoretically, every per cent. of alcohol by weight in a liquid should yield one and one-tenth per cent. of anhydrous acetic acid, or as much acetic acid per ounce as will neutralize five to six grains of pure carbonate of potassa. In good practice, it is found that two hundred gallons of spirit of fifty per cent. yield one thousand six hundred and sixty-seven gallons of vinegar, neutralizing thirty-two grains of the alkaline carbonate per ounce, or one thousand seven hundred and seventy-five gallons, of thirty grains neutralizing power: according to theoretical calculations, one thousand nine hundred gallons of thirty grain vinegar should be obtained, which shows a loss in practice of about six per cent. In many factories this loss is obviated, by causing the vapors from the acetifying tuns to pass over a surface of cold water, which absorbs any alcohol or aldehyde that may be evolved, and this water is afterwards used in extracting the soluble matters from fresh quantities of malt.

In some of the metropolitan establishments, a very large slightly conical tub or tun, fourteen feet wide at bottom, fifteen at top, and thirteen high, turns out as much vinegar as is in Germany obtained from six tubs, eight feet high and four feet wide. The larger mass of materials generates and maintains so much heat in the oxidation of the spirit, as to require no stove-heating in a properly constructed chamber. Two and a half feet above the bottom of this tun a false one is laid; the space over this bottom is filled with coopers' wood shavings and chips, and the room beneath is destined to receive the liquor as it trickles down on the true bottom, in order to be pumped up in continual circulation. At a moderate elevation the reservoir of the wash is placed, which discharges itself through a regulating stopcock or valve into a pipe at the bottom, which passes down through a pretty large hole in the middle of the lid of the graduator, and terminates a few inches under it in a cross pipe shut at the ends, which is made to revolve slowly by mechanical power, in a horizontal direction, round the end of the vertical pipe. This cross pipe is long enough to reach nearly to the sides of the tun, and being pierced with small holes in its under side, delivers the fermented liquor, in minute streams, equally all over the surface of the chips of wood. It thence falls into the lower part of the tun, through holes round the circumference of the false bottom, whence it is pumped up again, under certain modifications to be presently described. The air for oxygenating the alcohol into vinegar is supplied from two floating gasometers, which are made to rise and fall alternately by steam power. The ascending one draws its air from a pipe which passes into the centre of the tun, immediately under the false bottom, and, as it redescends, it discharges the air through a pipe into a cistern of water, which condenses and retains the alcohol vapor drawn off with the air. This water is used in making the next acetifying mixture. Fresh air is admitted into the top of the tun, by the sides of the vertical liquor pipe, which is somewhat smaller than the hole through which it passes. Proper valves are placed upon the pipes connected with the gasometer pump, whereby the air drawn off from the bottom compartment is prevented returning thither. A small forcing pump is employed to raise the liquor continually from the bottom of the tun to the cistern overhead. By this arrangement, good vinegar may be made in a few days without any perceptible loss of materials. The progress of the acetification in this apparatus is ascertained by testing the air for oxygen, as it is slowly drawn into the gasometers, or expelled from them. For this purpose a bundle of twine, which has been impregnated with a solution of acetate of lead, and dried, is set fire to, and plunged into a bottle filled with the air. In general, it is so well disoxygenated and carbonated that the ignition is immediately extinguished.

By regulating the warmth of the apartment, the motion of the gasometer, and the admission of air, the due progress of the acetification may be secured. The vinegar has an average strength of five and a half per cent. of hydrated acetic acid, and is immediately ready for market.—*Ure.*

Another process, not very unlike the preceding, patented by Mr. HAM of Bristol, is in operation at several works. The apparatus consists of a large vat, in the centre of which is placed a revolving pump, having two or more shoots pierced with holes, so as to cause a constant shower of wash—fermented wort—to descend from the top when they are set working. The lower part of the vat is charged with wash, the upper part with birch twigs, piled as high as possible, but without interfering with the revolution of the shoots. Between the surface of the wash and the joist which supports the birch twigs, a space of three or four inches is unoccupied, and one or more holes perforated therein, in order to admit a current of air, either direct from the atmosphere, or by means of a blowing apparatus. If the wash be maintained at a temperature between 90° or 100° Fahr., and the pump kept in continual motion, a charge may be acetified in a period of two, fifteen, twenty, thirty, or forty days, according to the quantity of liquid, and the mass of twigs through which it has to pass; but, generally, the birch twigs and liquid are so proportioned as to obtain the acid in fifteen or twenty days. The advantages offered by this modification are, that a wash made from raw grain with one-sixth of an admixture of malt, will yield a vinegar equal to that from malt alone; besides, any other liquor capable of fermentation, and producing alcohol, can be acetified as in the German process. The acetification can be arrested at any moment, and the current of air increased or diminished at will.

Messrs. NEALE AND DUYCK, of London, patented a process for the manufacture of vinegar from beet-root, in 1841. The method given by them is the following: —The tops and shoots of the beet are cut off, and the roots, after being thoroughly washed, are rasped into a fine pulp, with which a number of strong cloth bags are filled. These bags are placed in a powerful press, with a board or hurdle between every two, and subjected to pressure till the whole of the saccharine juice is extracted from the pulp. The strength of this juice will vary from 7° to 9° of the hydrometer, and must be reduced by the addition of water to 5°, and then boiled for a short time. The liquid, or *wort*, is now removed to the coolers, in which it remains until the temperature falls to 60° Fahr. It is then conveyed to the fermenting vat, adding half a gallon of yeast to every hundred gallons of the wort. When the fermentation is ended, the fermented wash is pumped into the acidifying vessel, and is there converted into vinegar. The acidifying vessel consists of a strong vat, capable of containing twenty-four thousand gallons, in the centre of which, a short distance above the bottom, a rose, or small inverted dome, is fixed, pierced with numerous small holes, and communicating by a pipe with a blowing apparatus. Upon the bottom of the vat, a steam worm lies, one end of which is connected with a steam boiler, and furnished with a steam-cock, the other end being open to the atmosphere.

The interior of the vat is divided into several compartments by means of diaphragms or perforated false bottoms, and the cover of the vat is provided with a valve which opens outwards upon a very slight pressure from within. The vat is likewise furnished with a thermometer, the bulb of which is immersed in the liquid contained in it, by which the temperature of the liquid is known.

Annexed is the mode pursued for converting the fermented wash into vinegar, by means of this apparatus: —Two thousand gallons of vinegar are first let into the vat, to serve as *mother* to an equal quantity of fermented wash, which is introduced at the same time; and a little yeast being added, the whole enters quickly into the acetous fermentation. After the action commences, air is forced into the apparatus by the blowing machine, which air, in its passage through the small holes in the false bottoms, is brought into intimate contact with the liquid, imparting to it a portion of its oxygen; the deoxidized air, and carbonic acid evolved from the vinous fermentation, being expelled through the valve in the cover, by the force of the current which is instituted through the vat. When the temperature, as indicated by the thermometer, falls below 70°, a current of steam is admitted into the worm by turning the cock, so as to maintain the heat of the vat between 70° and 80° Fahr. By this means the liquid will, in a few days, be converted into vinegar; and when that is effected, four thousand gallons more of the fermented wash are introduced, and the preceding process continued,—the whole eight thousand gallons will, in a few days, be converted into vinegar. Fresh charges are added and acetified, as just mentioned, till the vat contains twenty-four thousand gallons of vinegar; and when the acetous fermentation of the last charge has ceased, eight thousand gallons of vinegar are drawn off, and fresh wort added, and drawn off alternately, always keeping about sixteen thousand gallons of made vinegar in the vat.

FRUIT VINEGAR.—Apples, grapes, and other saccharine fruits, are expressed, the juice, with the addition of a little yeast, set aside in casks in a warm place—75° to 80° Fahr.—until the vinous fermentation has ceased, and then acetified by either of the preceding methods.

A very superior vinegar is made in Germany, and other continental states, from grape-sugar and the spirits produced from potatoes, beets, and molasses. The Excise laws of England, however, prevent the adoption of those materials in her manufactures, except under heavy duties.

In some factories, large quantities of sour ale and beer are converted into vinegar; but the product is much inferior to the vinegar made from wine or malt wort. The large amount of nitrogenous and other extractive matters which those liquids contain, undergoes a second or putrid fermentation after their alcohol is oxidized into acetic acid, and this quickly destroys the last traces of acid, leaving a liquid of a disagreeable odor, slightly resembling very stale beer. Sulphuric acid prevents the second fermentation for some time; still the vinegar has a nauseous odor, which renders it most objectionable.

Mr. J. C. KENT, of Upton-on-Severn, kindly informs the Editor, that when he first undertook the supervision of the manufactory of Messrs. KENT and SONS, the firm was in the habit of buying beer, ale, and porter, that had gone hard and sour, for conversion into vinegar; and on one occasion the bankrupt stock of a large brewery at Cavendish Bridge, in Derbyshire, was bought. Murmurs had reached them on several occasions that the vinegar, on being kept, lost its acidity; but when the above large quantity of beer came to be sent out as vinegar, the complaints became loud and frequent. It was found that the beer was the cause, and since that not one gallon of sour ale has been purchased by this firm. Some of the vinegar that was returned became exactly like vapid beer; it was not so putrescent as to smell, still it was a phase of the putrid fermentation. The same gentleman states, that it is impossible to make good vinegar from beer; and further, that although one or two manufacturers claim to be able to dispense with the addition of sulphuric acid to malt and grain vinegar, as mentioned further on, he has never been able to obtain a sample free from this acid.

Dr. STENHOUSE, in an investigation on sea-weed, showed that when such bodies are subjected to a fermentative action, at a temperature of 96° Fahr. with lime, acetic acid is generated in large quantities, and is found, united with the alkaline earth, in the form of acetate of lime. In three experiments with different varieties of sea-weed, he obtained as a result an average quantity of one and four-fifths per cent. of anhydrous acetic acid. He employed a temperature of 96°, and added hydrate of lime, gradually, with the view of keeping the mass slightly alkaline, till the fermentation had subsided; after which the liquid was filtered off, evaporated to dryness, and the residue heated, to decompose the mucilaginous matters, when crude acetate of lime remained. No attention has yet been paid to this fact, in the production of vinegar, on a manufacturing scale, although in some of the northern countries of Europe, as well as on some of the Scottish and Irish coasts, where sea-weed is plentiful, it might prove productive. The sea-weed seems to lose nothing of its fertilizing influence on account of the fermentation.

WOOD VINEGAR, or *Pyroligneous Acid.—Holzessig*, German; *Vinaigre de Bois*, French.—This species of Vinegar, to which much attention has been lately given, is, as the name implies, obtained from wood by destructive distillation, and it is the only one of the series upon whose formation no positive data can be elicited. Caloric is the moving cause which developes the acid, when wood is subjected to its influence in close vessels. The elementary components of the wood, after a certain amount of heat is applied, arrange themselves into combinations quite distinct from those in which they were originally; some of these are gaseous, while more are liquid; but the quantity of the latter depends upon the greater or less degree of heat applied in the distillation. The uncondensed products are—carbonic acid, carbonic oxide, olefiant gas, and light carbide of hydrogen; and the condensed liquids—acetic acid, tarry and other oleaginous substances, while a residuary charcoal remains in the retort. Hypothetically, the formation of acetic acid during distillation, may be demonstrated in various ways. The composition of wood may be represented as $C_6 H_5 O_5$, two eqs. equal...... $C_{12} H_{10} O_{10}$

Minus .... $H \ O$

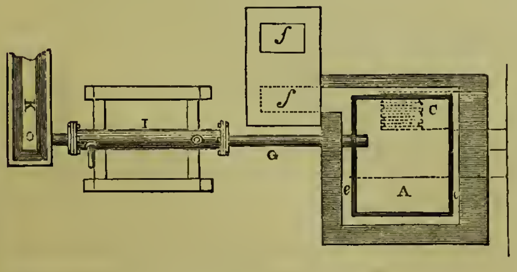
Equal three eqs. of anhydrous acetic acid, $C_{12} H_9 O_9$; consequently, it is only necessary to abstract a little oxygen and hydrogen—water—from the wood, in order to transform it into acetic acid. It may likewise be assumed that the olefiant gas evolved during the distillation, by combining with oxygen, generates the acid—

$$\underbrace{2\,(C_2 H_2)}_{\text{Olefiant gas.}} = C_4 H_4 + O_4 = C_4 H_4 O_4 = \underbrace{C_4 H_3 O_3,\ HO}_{\text{Hydrated acetic acid.}}$$

It is known that when these two gases are mixed in equal volumes, and the mixture enclosed over mercury in a bell glass, acetic acid is formed; the production of the acid, however, from the combination, requires considerable time. The facts which are observed in the actual distillation of wood are:—First, water passes off, being that which is extraneous to the wood; then, the decomposition of the wood itself gives rise to water and the acid, which is next eliminated; subsequently, condensable matters containing an excess of carbon, forming the tar and oily substance, and towards the close of the distillation, carbonic oxide and carbide of hydrogen are evolved, leaving a charcoal similar in form to the wood introduced. The distillation of wood is carried on in large cast-iron cylinders, or in square ovens made of stout sheet-iron, riveted firmly together, the heat being applied to them directly.

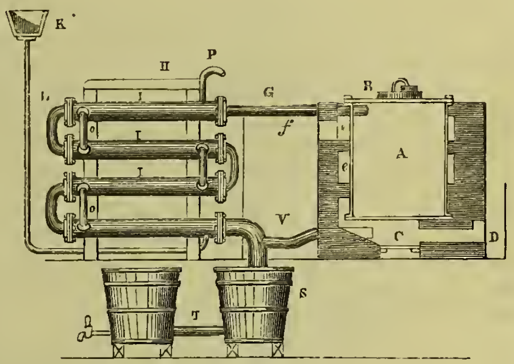
A convenient apparatus, for the distillation of wood, is annexed, of which Fig. 10 is a plan, and Fig. 11 an elevation. In these figures, A is a box made of cast-iron plates, bolted firmly, of one hundred cubic feet capacity, and imbedded in brickwork; B is a cover on the upper end of the box, through which the charge of wood is introduced, another such opening being at the opposite side—not shown in the figures—made air-tight by a cover such as B, from which the charcoal is drawn off; C, the firebars; D, the firedoor, through which the fuel is introduced; *e e*, the spiral course of the flame round the box, and *f f*, the flue passing into the chimney.

Fig. 10.



The iron pipe, G, conducts the gases, and other volatile matters evolved by the heat, to the condenser, consisting of a series of pipes, I, I, I, of a large calibre, through which the pipe, G, passes, leaving a surrounding space for cold water. The pipes rest one above the other on a wooden framework, H. Through L, a stream of water from the tank, K, enters the lower condensing pipe, and thence into the others by the connecting pipes, *o o*, till discharged by P, at a temperature reaching ebullition. The distilled vapors and gases, in their progress downwards, are partly condensed into a liquid, which falls into the air-tight tank, S, and thence by the connecting pipe, T, into another, collaterally placed, but at a lower level: V is a tube from the pipe G, projecting into the furnace, through which the uncondensed carbonaceous gases flow into the fire, where they are consumed. At first the fire is increased, and when the distillation has commenced, the gases discharged almost serve to maintain the heat sufficient to effect the decomposition of the charge.

Fig. 11



The usual time allowed for carbonizing each charge is twenty-four hours. After the wood is exhausted, the fire is withdrawn from the oven for six hours, so that the apparatus may cool, to allow the charcoal to be abstracted through the opening at the back, air-tight sheet-iron boxes being placed beneath the door to receive it. One hundred cubic feet of beechwood produce sixty per cent. of charcoal, as much brushwood being used to raise the heat required to carbonize the wood.

The apparatus in use at Nuits, and Rouen, in France, is the following:—In Fig. 12, A is a large sheet-iron cylinder, with an opening in the upper part of one of the sides, into which an adapter, B, is introduced; C is the cover of the cylinder, fitted tightly to it with bolts and screws. The cylinder being charged with wood, the cover, C, is fixed tightly in its place, and the cylinder hoisted by means of a crane, D, fixed adjacent to the furnace, and deposited in an upright cylinder of brickwork, which may be covered, at will, by means of a dome, E, made of brickwork. The cylinder being charged and deposited in its receptacle, the fire is lighted, and the tube, C, through which the distilled products pass off to the condenser, connected, and well luted to the adapter, B. The condenser is similar to that attached to the oven at Fig. 11, consisting of a series of pipes, I, I, I, through which C passes. Water from the pipe, L, enters the pipes, I, I, I, by means of F and the connecting-pipes, *t*, near the curvature, the heated water being discharged by the pipe, *o*. The condensed products pass off into the covered receiver, and a pipe, P, conducts the uncondensed gases back to the furnace, where they are consumed. The pipe, P, terminates a few inches above the ground in the ashpit, in the form of a rose, N, similar to a watering-can, in order that the flow of gases may be distributed through the fire; M is a stopcock, to regulate the quantity of gas entering the furnace.

In some factories there are different methods of condensing the products; air, in a few instances, is the medium by which the vapors are condensed. The evolved products of the distillation are made to traverse an extensive range of piping of large diameter, and in some cases the vapors are conducted through a series of casks, connected together by pipes. The most effectual mode of condensation is water, and, wherever at hand, is generally adopted. About twenty-four hours are usually allowed to work off each batch of wood.

Fig. 12.

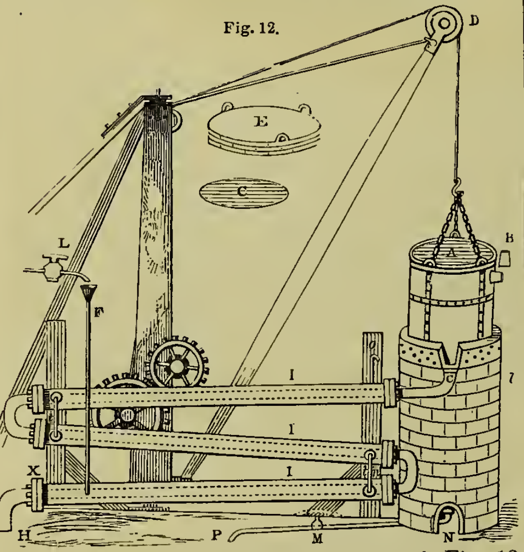


Fig. 13.

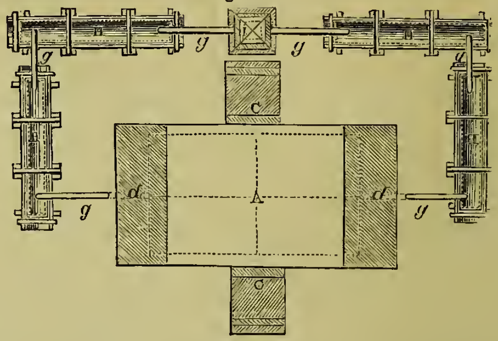


Fig. 14.

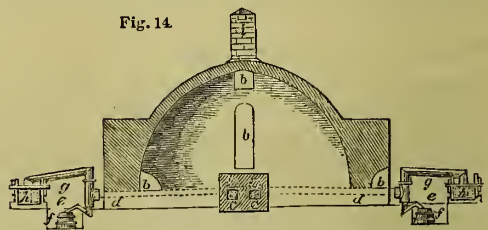
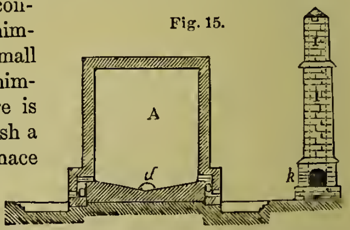


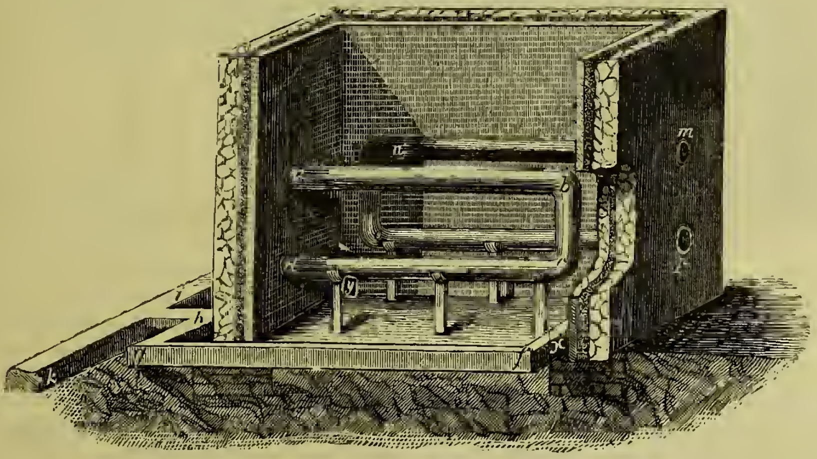
Fig. 15.



The carbonizer of M. Schwartz is shown in Figs. 13, 14, and 15. Fig. 13 is a bird-eye view of the furnace; Fig. 14 a section of the elevation, following the lines, *d d*; and Fig. 15 another section, following the lines, C C. In the *ensemble* of these figures, the annexed objects are distinguished:—A A, the space where the wood is carbonized; *b b b b*, apertures through which the wood is introduced, and whence the charcoal is withdrawn; C C, the fires which heat the furnace; *d d*, openings through which the smoke, carbonic acid, acetic acid, oleaginous and tarry matters, pass off, through the pipes, *g g*, and thence through the condenser into the chimney; *e e* are crooked pipes, descending from *g g*, which convey the tar condensed in *g* into the vessels, *f f*—Fig. 14—the bend in the pipes, *e e*, prevents the access of air into the apparatus; H H H H are wooden canals, wherein the acid and oleaginous matters condense; I is the chimney, and *k* a small opening in the chimney, where a fire is lighted to establish a draught. The furnace walls are of fire-brick, or they may be doubly lined with brick, and the intervening space filled with aluminous earth and sand. At first the furnace is charged with the heaviest blocks of wood, and between these smaller wood is introduced, for the purpose of making the interior more permeable to the action of the fire. All the orifices of the furnace are then closed, and the fires at C C lighted, the current of air being instituted in I, as above said. The blaze of the fire traverses the furnace and carbonizes the charge of wood, and the smoke and other vapors from the furnace pass by the exit pipes, *d d*, into *g g*, whence they escape to the condensers, H H, and thence to the chimney, I. The charge is known to be completely carbonized when the smoke issuing at I, which is at first black and heavy, becomes bluish and light. The chimney passage is then closed, and the opening of the pipes, *d d*, stopped up with wooden plugs, and then well luted with some plastic clay; the firedoors are closed, and the furnace left to cool. At the end of the second day, two holes in the top of the furnace, which hitherto had been closed air-tight, are opened, and water introduced to extinguish the red-hot charcoal; the openings are again closed for a longer period, and when the furnace gets a little colder, more water is added. If any red sparks are observed, the opening and pipes must be carefully stopped up, so as to prevent the formation of a current of air, as this would occasion the combustion of the charcoal, and consequently lessen its produce. After complete cooling, the charcoal is raked out by the apertures, *b b*, and another charge introduced. The principle of carbonization in these kinds of furnaces is different from the others already mentioned, inasmuch as the blaze from the fire never comes in contact with the wood in the latter, while in SCHWARTZ's furnace the blaze permeates the furnace entirely; but so long as a competent supply of fuel is kept on the fire, C C, no oxygen passes into the interior to consume the charcoal, and the wood is carbonized quicker. Another advantage which this furnace possesses is, that small wood may be employed to burn in C C, and the acid and other valuable products of this likewise are collected in the condensers, H H. What more particularly distinguishes SCHWARTZ's furnace above LACHABEAUSSIÉRE's is, that no air can enter it but through the fires, C C, and that there is no loss from the combustion of charcoal. The cost of this furnace is about £120, the capacity being nearly six thousand cubic feet.

REICHENBACH's carbonizing furnace consists of a square oven, made partly of firebrick and partly of ordinary bricks; the interior lining, represented in Fig. 16, is composed of the firebrick, and the outer case is of the ordinary material. The oven is heated by means of tubes, which traverse from one end of the case to the other, and are seen in *a b c d*, *m n o p*, in the figure; these tubes are from one to two feet in diameter. Heat is applied by lighting a fire in the tubes at *p* and *a*, which raises the temperature so high as to cause them to glow. The wood in the surrounding spaces of the oven abstracts the heat, and is thereby carbonized, the volatile products of which pass off at the bottom of the oven, through the openings at *x*, into the canal, *f g h*, and through *y*, at the opposite side, into a similar canal: both products intermix in the canal, *k i*, where the tar is partly deposited. From the tube, *k i*, the acetic acid vapors are carried off to the condenser, as in the ordinary process of the manufacture.

Fig. 16.



The chief pyroligneous acid factories in England are in the counties of Gloucester, Northumberland, Lancaster, and Monmouth; and one in Glamorganshire in Wales. Cylinders of varied length, from six to ten feet, and two and a half to four feet in breadth, are

Fig. 17.

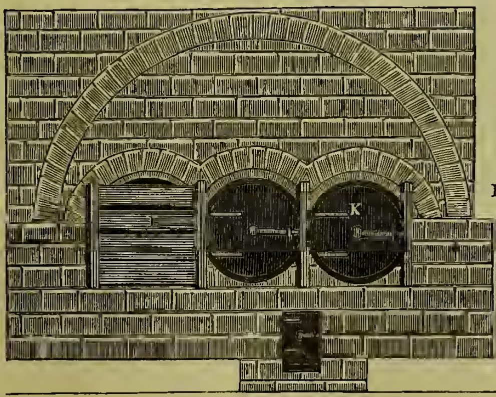
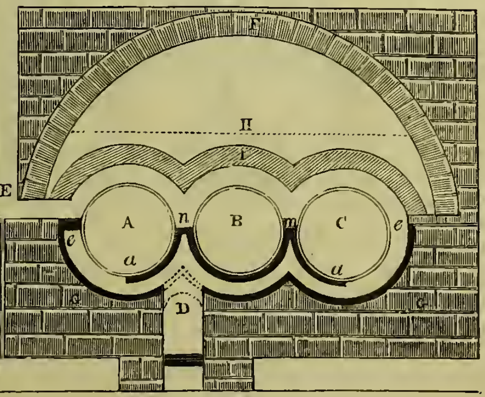


Fig. 1



employed. These are placed horizontally in brickwork domes, the front and back ends being closed by doors which swing on stout hinges, or by plates screwed firmly to these openings. A pipe issuing near the convex extremity of the further end of the retort, carries off the gases and condensable products to the refrigerator. A general view of the retorts and condenser is seen in Figs. 17 to 22. Fig. 18 presents a section of cylinders, A, B, and C; and in Fig. 17 is seen their position enclosed in brickwork, with the doors, K, closed. The fire is at D, Fig. 18, and the space, *e e*, shows the course of the flue round the cylinders, till it reaches the chimney, E. The passage of this flue is more clearly seen in the plan, Fig. 20, where the dotted lines, *d d*, *et cetera*, are the circuits it makes. The space, A, B and C, indicates the cylinders and the pipes attached to them for conducting the distilled products to the tank, D, where most of the tar is deposited, and the partly depurated product issues through a small pipe into a condensing tube. This is more perspicuously seen in the elevation of the cylinder and tank, as shown in Fig. 21. Fig. 22 is a section of the tank where the tar is deposited; the tank is protected by a cover, which fits into the enlarged part or groove at the top of the sides of the tank, acting as a water lute, as is seen at *h*. The pipe, *i*, carries off the acetic acid vapors to the serpentine pipe in the large tub, C, which it enters at *k*, in the figure. Beneath the tank, A, a tub, *n*, is placed; both are connected by *m*, that enters at the bottom of the tank. The tarry matter, as it accumulates in the tank, falls through the pipe, *m*, into the tub, *n*. F is a tub placed below the condenser, C, where the acid is collected, and the uncondensed gases pass off through the pipe, D, and are consumed at *l*, so as not to corrupt the air in the factory. The arc, B, Fig. 22, shows the position of the condensing vessel with regard to the cylinders, it being the same as F in Fig. 18. The space at H may be used as a torrefying chamber when preparing the acetates, described at page 46. Sometimes two of these cylinders, placed in the same dome of brickwork, are heated by one fire, the flue playing round each, as in Fig. 23, where *a a* are the cylinders; *f f f* the fires; *c c c*, ash-pits, and *o o o* the course of the flue to the chimney. Even five such carbonizers, placed in one arch, are heated by

Fig. 19.

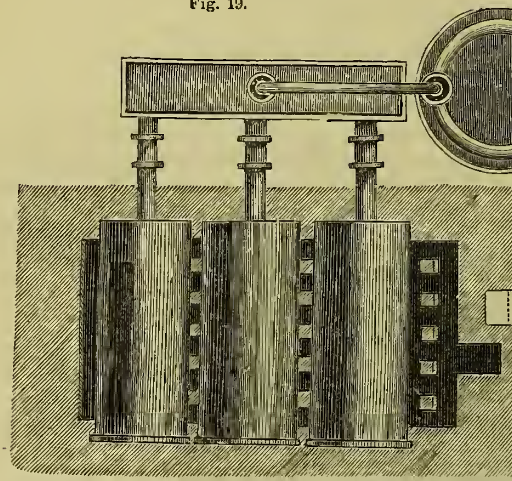


Fig. 20.

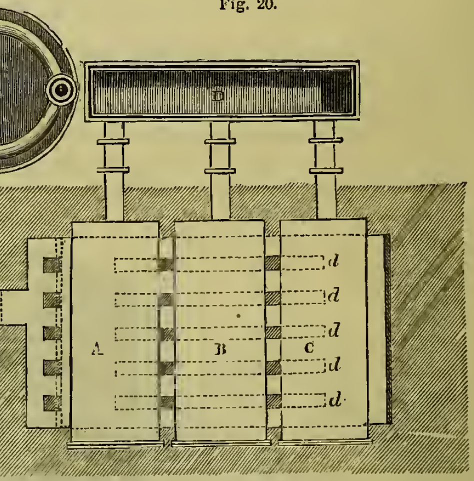


Fig. 21.

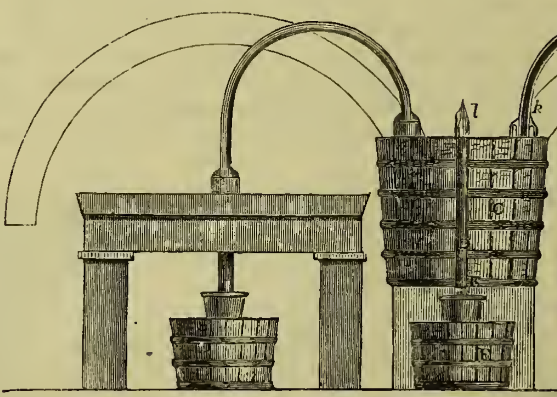
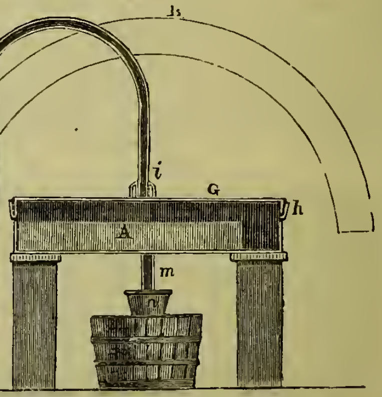
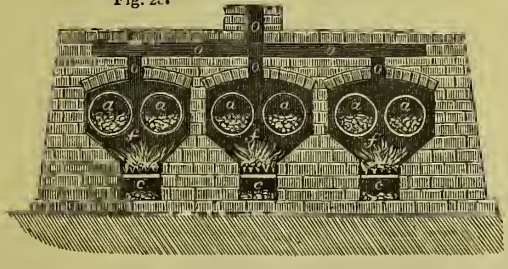


Fig. 22.



two fires. Such is the arrangement at Pitchcombe Chemical Works, near Stroud, Gloucestershire, where the cylinders are nine feet by two feet ten inches; thirteen of which are capable of holding five and a half *cords* of wood, each cord being sixteen feet eight inches in length, and two feet two inches in breadth, and the same in depth, the weight of which, according to the state of freshness or otherwise of the wood, is between twenty-three and twenty-five hundreds. One ton and a half of coal serve to carbonize the whole. The usual time allowed to carbonize each charge is twenty-four hours. Factories which are carried on at Risca and Abercarn, in Monmouthshire, by the same proprietor, form conjointly the largest in the kingdom. In the Risca Works, cast-iron cylinders, six feet long by four feet in diameter, are used, each being capable of holding about two tons of wood, or three-fourths of a cord. Wrought-iron chests are likewise serviceable, having an iron pipe six inches diameter passing up through the centre of the chest, in order to convey the heat to the interior. Each chest is capable of holding a cord and a quarter of wood—one hundred and sixty cubic feet, a cord of wood being one hundred and twenty-eight cubic feet—which weighs about three tons and a half. At Abercarn, eight square ovens, with boxes, are the variety of carbonizers, each oven being capable of holding one cord of wood—one hundred and twenty-eight cubic feet. Twenty-four hours is the time usually allowed to work off each charge, but if the demand for the distilled products be urgent, the charge may be exhausted in sixteen to eighteen hours. In this case, the products are not so much as when the distillation is carried on slowly.

Fig. 23.



As Cornbrook Works, near Manchester, the cast-iron cylinders are six feet long by three feet diameter, with square doors, which hang on stout hinges. Generally, six tons of wood are carbonized by one and a half ton of coal; one fire being made to heat two such cylinders, placed adjacent to each other in the same arch.

At Breeme, near Lidney, in the forest of Dean, there are eight large square ovens, each capable of containing two sheet-iron boxes, four feet six inches by two feet nine inches in interior measurement. In each of these boxes about half a cord of wood is placed, and as the wood is piled up above the top of the sheet-iron box, the ovens are required to be of a size proportioned to this height. The doors of the ovens are on hinges, fastened and luted, when the charges are enclosed in the usual manner. These ovens are charged once a day; but as the wood is light, twenty-four hours are more than sufficient to effect its carbonization. The boxes, when charged, are run along a railroad into the ovens, and withdrawn in a similar manner, whereby much labor is saved.

At Lougher, near Swansea, they use a peculiar sort of apparatus—a large sheet-iron carbonizer, divided internally into six compartments, into which six sheet-iron vessels, of four feet in height and two feet broad, fit; the whole forming a cylindrical shape similar to the outer case. There is only one opening in the top of the carbonizer, through which the vessels containing the wood are introduced; but there is a movable framework in the bottom of the outer vessel, by means of which each receptacle is brought directly under the orifice, and the charged box lowered into it by a crane. When charged, this aperture is closed by a sheet-iron door and firmly bolted, then luted in the ordinary way, and heat applied. The sheet-iron case is imbedded in brickwork, and the fire directly under it, the flue rising spirally about the carbonizer. A similar apparatus to this is in use at Deptford.

Upon a comparison of all the modifications of carbonizing retorts sketched, it will be evident that the cylinders are more adapted for the distillation of the large billets, or heavy cord wood of Gloucestershire, and the refuse ship-timber of Glasgow, Newcastle, and Liverpool.

The most economical are cylinders between eight and ten feet in length, and from two and a half to three feet in diameter. On the contrary, where light wood is used, such as that generally carbonized in the Welsh factories, the square ovens suit better; however, as the supply of wood is always subject to variation as to its bulk, it is more satisfactory to have both forms of apparatus on the premises. From the cylinders, the charcoal is generally raked out at the door at the opposite end, into sheet-iron boxes, or square pits sunk in the floor, and lined with firebrick; the chests and pits are capable of being perfectly closed.

In many factories, the charcoal is abstracted from the carbonizing cylinders by means of the following apparatus:—An iron shield, almost the size of the interior of the cylinder, is placed near the mouth of the retort, to which a chain is attached, that runs through the whole length of the carbonizer. The workman, by seizing this chain with a suitable implement, draws out the whole of the charcoal nearly all at once, and with less risk of breaking it than when the rakes are employed.

The relative amount of charcoal, as well as the gaseous and liquid products, depends on the species of wood subjected to distillation, as also upon the regulation of the proper heat to effect the same. The temperature should at first be gentle, gradually increasing in proportion to the time, till towards the end it approaches an incipient red heat, in order to dissipate all the volatile products from the wood. The strongest acid is generally obtained from timber of slow growth on dry soils; next from timber grown on moist ground; and lastly, from pines and resinous trees. The productions of the latter variety are not, however, so inferior as generally stated, when proper attention has been paid to the regulation of temperature, and complete carbonization of the charges. This will be seen under the distillation of spent dyewoods, sawdust, *et cetera*, as carried on with success by Mr. A. P. HALLIDAY, of Salford, whose apparatus is there represented.

The following tabular view of the amount and strength of the products obtained from the distillation of several varieties of wood, is taken from the work of STOLZE. The quantity of the varieties of wood submitted to destructive distillation was *one pound*, a quantity which will, in the generality of cases, form a precedent for the manufacturer on the large scale:—

One Pound of Wood.		Weight of Acid.	One ounce of Acid neutralized of pure Carbonate of Potassa.	Weight of Empyreumatic Oil.	Weight of Charcoal.
	Botanical Names.	Ounces.	Grains.	Ounces.	Ounces.
White Birch	Betula Alba	7⅛	55	1⅜	3⅞
Red Beech	Fagus Sylvatica	7	54	1¼	3⅝
Large-leaved Linden	Tilia Plataphylla	6⅞	52	1⅞	3⅝
Oak	Quercus Robur	6⅞	50	1¼	4⅛
Common Ash	Fraxinus Excelsior	7¼	44	1⅜	3¾
Horse Chestnut	Esculus Hippocastanum	7⅜	41	1⅝	3½
Lombardy Poplar	Populus Dilatata	7⅜	40	1⅜	3¾
White Poplar	Populus Alba—abele	7⅜	39	1¼	3¾
Bird Cherry	Prunus Padus	7	37	1¼	3⅜
Basket Willow	Salix	7⅜	35	1¼	3½
Buckthorn	Rhamnus	7¼	34	1⅜	3½
Logwood	Hematoxylon Campechianum	7¼	35	1½	2
Alder	Alnus	7⅜	30	1⅛	3½
Juniper	Juniperus Communis	7¼	29	1¾	3⅝
White Fir	Pinus Abies	6⅜	29	2¼	3⅜
Common Pine	Pinus Sylvestris	6¾	28	1⅞	3½
Common Savine	Juniperus Sabina	7	27	1⅝	3⅝
Red Fir	Abies Pectinata	6⅜	25	2¼	3¾

Eighty-four Pounds of Wood.	Charcoal.	Charcoal per cwt. of Wood.	Acid liquor.	Sp. gr. of Acid liquor.	Sp. gr. of Acid liquor saturated with Lime.	Measures of Soda to neutralize Acid liquor.	Incondensable products.	Real Acid.
Birch,	23½	31·33	45	1·046	1·080	70	15	1·86
Elm,	21½	28·66	45½	1·036	1·075	83	17½	2·26
Willow,	18	24·00	49	1·029	1·045	29	17	0·77
Beech, low temp.	24	32·00	46	1·039	1·090	115	14	3·06
Do. high temp.	20	26·64	47	1·034	1·067	90	17	2·40
Laburnum,	20	26·64	46	1·030	1·055	75	18	2·00
Ash,	23	30·68	48	1·035	1·078	92	13	2·45
Alder,	20	26·64	48	1·030	1·065	70	16	1·86
Hawthorn,	20	26·64	27	1·040	1 100	140	37	3·73
Young Oak,	28	37·33	39	1·038	1·085	115	14	3 06

Three hundred and thirty-six Pounds of Wood.	Charcoal.	Charcoal per cwt. of Wood.	Acid liquor.	Sp. gr. of Acid liquor.	One ounce neutralized grs. of Bicarbonate of Potassa.	Dry Acetate of Lime produced.
Beech,	84	28·00	180	1·029	9½	25
Walnut	72	24·00	150	1·018	7	14½
Birch, cut three years	70	23·33	120	1·031	11	13
Oak,	91	30·33	190	1·022	8	24
Ash,	90	30·00	190	1·024	8	22
Apple,	70	23·33	200	1·017	6	18
Wych Elm,	70	23·33	180	1·018	8	16
Maple,	77	25·66	145	1 018	6	20

The *ensemble* of three works in the neighborhood of Paris showed the following products from four thousand pounds of wood—beech and oak:—

Charcoal,	1,014 lbs.	
Acid Liquor,	2,335 "	sp. gr. 1·027 = 416 lbs. of dry [acetate of lime.
Tar,	330 "	

The following products were obtained at the works of M. MOLLERAT, at Nuits, from 1,000 steres of wood, weighing 5,120 cwt.:—

Charcoal,	1,280 cwt.
Pyroligneous acid,	850 "
Acetic acid,	54 "
Acetate of lead,	152 "

In a well-conducted establishment in England, the annexed were the quantities of crude acid liquor obtained by the distillation of 1,634 cords of wood; each cord of wood weighing 512 cwt., according to the longer or shorter time allowed to intervene between the cutting and the using of the wood:—

174 cords produced	23,923	gallons of about 10 lbs. each.	
160	27,720	.. ..	..
252 . ..	30,424	.. ..	..
318	40,584	.. ..	..
330	55,900	.. ..	..
400	50,700	.. ..	..

The subjoined is one of the monthly statements of works in the vicinity of Paris, in which the wood is carbonized by heat from the coke ovens:—

DR.	frs.	c.
1,000 Hectolitres of coal, at 50 frs. the 15 hecto.,	3,333	33
500 Steres, half cords, of wood, at 9 fr. 20 c.	4,600	00
Wages of coke-oven man,	120	00
Wages of six workmen,	450	00
Wages and lodging of two carmen,	200	00
Keep of two horses,	180	00
Salary of director of works,	200	00
Wear and tear, calculated at ten per cent. on the value of the plant—60,000 frs.	500	00
Five per cent. interest on capital,	416	00
Rent of ground and cellars for charcoal,	100	00
Frs.	10,099	33

CR.	frs.	c.
1,520 Hectolitres of coke, at 49 fr. the hecto.,	4,312	00
30 Hectolitres small coke, at 32 fr. 50 c.	975	00
750 Loads of charcoal, at 6 fr.,	4,500	00
150 do., second quality, 5 fr.,	750	00
50 do., third quality, 4 fr.,	200	00
20 do., powder, 2 fr. 50 c.	62	50
200 Casks pyroligneous acid, at 15 fr.	3,000	00
Tar,	165	00
Frs.	13,964	50

One franc equals ten pence English; one hundred centimes are equivalent to a franc. The French hectolitre is a measure of capacity, containing one hundred litres, equal 22·009668 imperial gallons; 4·5434579 litres equal an imperial gallon.

Mr. A. P. Halliday, of Salford, has obtained a patent for the manufacture of pyroligneous acid, *et cetera*, from sawdust, spent bark from tanyards, and dyewoods exhausted of their coloring matters, which is in operation at the works of Messrs. Hervey, Peak, and Hervey, the largest and most eminent manufacturers of decoctions in this kingdom; at the works of Messrs. Hadfield and Renney; and at Messrs. Halliday, Pochin, and Co. For a long time the distillation of sawdust was unsuccessfully attempted, the apparatus used being applicable to the decomposition of the material; for on being introduced into either the ovens or cylinders, a layer of carbonized sawdust coated the retort so effectually, when the temperature was raised, that the further progress of the decomposition was arrested by the non-conducting property of this hard layer of minutely divided charcoal.

Fig. 24.

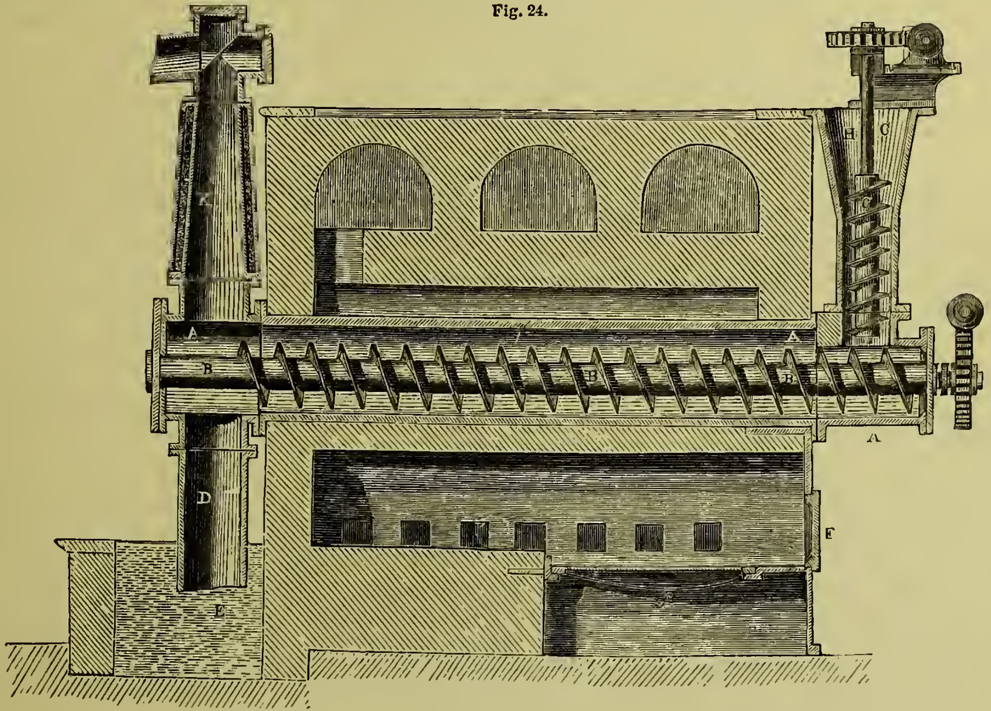


Fig. 24 is a drawing of the apparatus patented by Mr. Halliday, by which the preceding obstacle is overcome. The sawdust, spent dyewood, *et cetera*, are introduced into a hopper, H, placed above the front end of an ordinary cylinder, A A, in which a vertical screw or worm, C, revolves, conveying the material, and in the proper quantities, to the cylinder, placed in a horizontal position, and heated by means of a furnace, F. Another revolving screw or worm, B B, keeps the material introduced into the retort by C in constant agitation, and at the same time, moves it forward to the end. During its progress through the retort, the materials are completely carbonized, and all the volatile products disengaged. Two pipes branch off from the ulterior part of the retort, one, D, passing downwards and dipping into an air-tight vessel of cast-iron, or a cistern of water, L, into which the carbonized substance falls; the other ascending pipe, K, carries off the volatile products of the distillation into the condenser, consisting of pipes of copper or iron, immersed in or surrounded by water. Messrs. Hervey and Co. convert all the spent dyewoods of their manufactory into pyroligneous acid, and the charcoal obtained, when ground finely, answers well for steel manufacturers and iron founders.

The quantity of acid obtained from spent dyewoods, equals the amount usually derived in the ordinary distillation of wood. Messrs. Hadfield and Co., and Messrs. Halliday and Co., use sawdust, the produce from which is found greatly at variance with the statements set forth in chemical and manufacturing works—that *pine* and such resinous woods yield comparatively very little acid. Practically, eight retorts of the above description, fourteen inches diameter, produce as much pyroligneous acid in twenty-four hours, as sixteen retorts, three feet in diameter, during the same time, yield when worked on the old system. The charcoal from sawdust is extensively used as an ingredient of artificial manure, and many printers use it as an absorbent in the urinals attached to their factories. Charcoal being an excellent disinfectant, the nuisance that would arise from such cisterns is completely abated. Moreover, the Messrs. Hargreaves, of Accrington, state, that when the charcoal is saturated, the effluvia is taken away, and the ammonia, *et cetera*, arising from the decomposition of the nitrogenous compounds of the urine, are retained, so that it offers a ready and economical means of transferring these fertilizers to the soil.

The average produce from eight retorts, taken for many weeks, carbonizing twenty-two tons of sawdust weekly, is the following:

Pyroligneous acid 10° Twaddle = 1·05,	2484 gallons.
Tar,	240 "

to which, by way of comparison, is subjoined the average yield per ton of oak, when carbonized in the ordinary cylinders.

Weight of wood,		2240 lbs.
" pyroligneous acid,	1277 lbs.	
" charcoal,	600 "	
		1877 "
Loss—uncondensable gases,		363 "

According to the state of dryness of the wood when submitted to the retorts, the products are a little more or less; but generally the range of produce is between one hundred and twenty-four and one hundred and twenty-seven gallons of 6° Twaddle, or 1·03 spec. grav., and six hundred pounds of charcoal. From the preceding, it is evident that the same quantity is obtained from the sawdust, and of a far higher specific gravity.

The average price of oak wood is eighteen to twenty shillings per ton, and for cutting this in convenient billets for the retorts, *et cetera*, the cost is usually about two shillings to two and sixpence. About seven hundredweight of coals are found sufficient to carbonize one ton of wood. The tar obtained in distilling pine wood sawdust is of equal quality to that imported.

In the vicinity of Manchester, where exhausted dyewoods and sawdust are plentiful, a decided advantage in the yield and quality of the products is to be gained by operating upon those materials

Messrs. Solomons and Azulay patented a process, the main feature in which was the transmission of steam heated to a high temperature through the mass of material. By this method, every particle is exposed to the superheated steam, and completely carbonized. The charcoal left is well adapted for manuring purposes; besides, we have all the products ordinarily obtained in the ligneous distillation. The steam accompanying the other products renders them dilute; these vapors are, however, made subservient in concentrating the condensed products as they pass to the condenser; for they are made to traverse a coil of piping placed in a pan of the distillates. If this had not been suggested by a chemist, the patent could never be advantageously worked. The heated steam prevents the deposit of tarry and other resinous matters; consequently, no choking of the pipe need be apprehended.

The following brief sketch of the pyroligneous acid manufacture, has been transmitted to the Editor by Mr. John Randall, the manager of the Pitchcoombe Works at Stroud, and who has been there since their commencement in 1842.

Mr. Randall states:—It remains still a disputed point whether small or large retorts are preferable. After a trial of different sizes, and some years' experience, he considers a retort of moderate dimensions the most convenient and serviceable. Those in use here are nine feet and a half in length, and two feet and a half in diameter, enclosed in brickwork, and placed horizontally, three or five in a set.

They are secured in front by lids, fastened by means of a cross bar. At the back there is an exit pipe, eight inches in diameter, connected with a main pipe. From this the liquor is conducted by a series of pipes, immersed in water, into a large tank. Retorts set in the method described are heated more economically, and the charcoal is good.

Each retort holds about half a cord of wood, which, when of beech, of the average dryness, weighs about twelve hundred-weight. These retorts are charged once in twenty-four hours. As to the quantity of liquor produced from a given weight of wood, of course much depends on the condition of the wood, whether green or dry—that which has been cut down about six months is the best for practical purposes, the liquor being stronger in acid. A cord of wood in this state yields from one hundred and twenty to one hundred and thirty gallons of liquor, *id est*, acid, water, naphtha, and tar, leaving in the retort, charcoal, about one-fifth of the weight of the wood originally employed. The next process is to separate these various products, and for this purpose the liquor is pumped up into copper stills, and, for safety, steam heat is applied. Naphtha, in a weak and impure state, comes over first, then the pyroligneous acid, leaving a tarry residuum in the retort. Some manufacturers prefer adding lime to the liquor in the tank, before it is transferred to the stills: this, perhaps, is best for the production of naphtha, but it involves the necessity of making black or brown acetate of lime, which, from its inferior quality, is often difficult of sale, unless at a low price.

After distillation, the acid is removed to large tubs or vats, and neutralized with lime. It is then allowed to stand for a few hours, and the clear solution siphoned off into evaporating pans. The vessels used here for this purpose are made of wrought-iron, of an oblong shape, about nine feet in length, four feet in width, and two feet in depth; they contain about four hundred and fifty gallons. The solution is boiled down to a proper consistency, put into draining buckets, and then removed to a drying stove. This is the ordinary process; but when the acetate is required of superior quality, the solution should be properly evaporated, then allowed to stand for eight or ten hours, carefully drained off from its sediment, and boiled to its crystallizing point. Simple distillation, though it separates a large portion of tarry matter, never renders the pyroligneous acid pure; this can only be effected by neutralizing the acid with carbonate of soda, evaporating the solution to dryness, and then subjecting the exsiccated mass to fusion. The *black cake*, as it is termed, is redissolved, boiled to the crystallizing point, and drawn out into large shallow vessels to deposit the salt.

The trade has been in a depressed state for the last few years; and, indeed, it is liable to such fluctuations that there is not sufficient inducement for a capitalist to embark in it.—*Randall.*

M. Paur has recently published a method which he follows in the preparation of acetic acid, and the acetates from the product of the distillation of wood, by which he dispenses with the labor of distillation, evaporation, and for the most part the torrefaction attendant upon the processes generally pursued in this branch of the manufacture.

His method consists in presenting to the vapor of acetic acid, during the operation of the carbonization, a substance which seizes exclusively upon it, and thereby concentrates it.

The bodies which will the most readily satisfy this condition, are those bases whose acetates are not decomposable at the temperature of the operation; such as potassa, soda, baryta, lime, magnesia, *et cetera;* and the carbonates of these same bases, or any other salt whose acid can be displaced by the acetic acid. The author gives the preference, according to locality, to lime, a calcareous carbonate, magnesian carbonate, or carbonate of soda; the first three, because of their low price; the last, because it will yield directly the acetate of soda,—a product prepared at a future stage for the entire purification of the acid.

This process may be applied, whatever be the mode of the carbonization. The manner in which it is adapted to carbonization *en meules*—piles or masses of rough wood covered with earth—will now be described.

It is well known that carbonization *en meules* is effected by the heat produced by means of the combustion of a certain quantity of the wood of the pile, when ignited. Orifices left at the foot of the pile give access to the air necessary for combustion; others pierced at different heights and in different positions, by the workman charged with directing the progress of the carbonization, serve for the escape of the products of combustion and distillation. In these last orifices, at the point where the workman has judged it necessary to carry the draught, M. PAUR introduces tubes into the earth of about an inch interior diameter, and half an inch in thickness, which, dividing over all the pile, terminate in bundles, in numerous recipients distributed quite round the mass. These pipes may be composed of several ends or short pieces, connected by jointings, so that, when the progress of the carbonization requires the displacement of the orifices for the emission of the smoke, the extremity only of the tubes may be removed, without the necessity of deranging the receivers.

The latter are simple casks, of fourteen inches diameter, and three feet and a quarter in height, into which the tubes lead by one extremity, and which are filled, in whole or in part, with pieces of lime, carbonate of lime, or carbonate of soda, divided into fragments varying in size according to the state of porosity of the matter, and leaving between them interstices, which permit the passage of the vapors.

Acetic acid and the other products which escape from the wood, are conducted by the pipes to one of the extremities of the cask, and traverse the different layers of carbonates or of lime, which fix the acetic acid, whilst the other products escape at the other extremity of the receiver.

It is proper to remark, that this process presents one advantage over that by refrigeration; namely, that considering the temperature maintained in the interior of the casks, much less tar is condensed, which renders more easy the subsequent purification of the acid.

The acetate of lime obtained in this manner, may be submitted to the same operations as in the processes at present in use.

It would be possible, under certain circumstances, in place of particular receivers, to introduce into the midst of the pile, in the intervals left between the logs, the substance intended to unite with the acetic acid.

There are some factories which expressly distil the wood in close vessels to obtain the acetic acid. For these, the method described would still have great advantages. In fact, there would be nothing to prevent so regulating the temperature of carbonization, that the acetate of soda produced in the apparatus should not itself be decomposed, while leaving this temperature sufficiently high to destroy or expel the tar, in such a manner that the torrefaction would be combined with the carbonization, so as to obtain, at one operation, a concentrated and purified body.

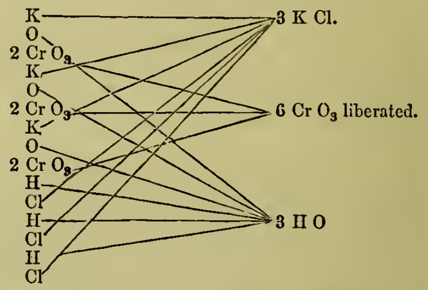
PYROXYLIC SPIRIT, or WOOD NAPHTHA.—PURIFICATION OF THE PRODUCTS OF DISTILLATION.—The distillates of wood are received in a tank or some suitable vessel, and on allowing the whole to rest for some time, the excess of tarry and other resinous and oily matters precipitates, the spirit and acid liquor forming a supernatant layer, which may be drawn off into another tank by means of an overflow pipe or siphon. If the liquids, in their passage from the first tank, be made to percolate a filter of coarse gravel, a large quantity of the matters held in suspension by the acid liquor is separated. The purification of the spiritous and acid products is effected in two ways: first, where the spirit is distilled directly from the crude liquor, and secondly, where the acid is neutralized with milk of lime, and then submitted to distillation to obtain the spirit. In the first instance, copper stills of about five hundred gallons capacity are used, into which the liquor is pumped, and heat applied by means of coils of copper pipe placed in the interior of the stills, through which steam from an adjacent steam-boiler is forced; in other cases the heat is applied externally, either by steam-pipes coiling round the still, or by the direct application of fire. The distillation is continued till all the spirit has passed over, which is known by throwing a portion of the distillate on a bright fire—the spirit inflames, giving a whitish light.

In most instances, the whole of the naphtha is expelled when about one hundred gallons are condensed in the receiver. When there are no more vapors eliminated, the receiver is changed, and the distillation of the acid liquor proceeded with till all the liquid has nearly passed over, the tarry and oleaginous products remaining being run off through a stopcock in the bottom of the still into a tank. Should the acid be not directly wanted, after the expulsion of the spirit, the remaining four hundred gallons may be drawn off into the tank, and allowed to rest, so as to deposit the excess of impurities, and afterwards pumped up to other vessels when required. Some manufacturers first neutralize the acid liquor by means of hydrate of lime, and afterwards distil the spiritous and crude acetate of lime liquors in sheet-iron stills or boilers to obtain the naphtha. Fire is applied directly to the under part of the boiler. The remaining acetate of lime liquor is drawn off, and allowed to remain in tanks or reservoirs till required for use. The deposit of tarry matters which accumulates in the first receiver of the condensing apparatus, attached to the wood carbonizers, is also submitted to distillation, and the crude spirit therefrom added to former portions.

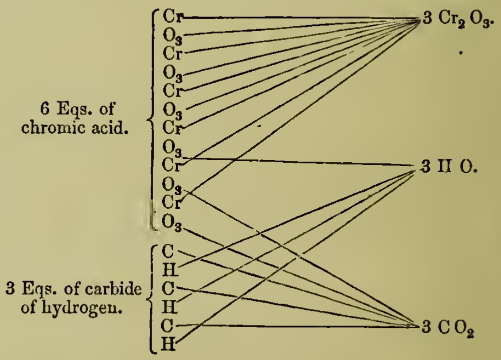
The further purification of the crude spirit obtained in the preceding distillation, is effected by repeated rectifications, over caustic lime at first, and then over a mixture of lime and caustic potassa; and, in order to detach the small quantity of ammonia that is formed, the final distillation of the product is carried on with a little sulphuric acid. In some factories they rectify the distillates over chalk, and in some others over chalk and bicarbonate of soda. Copper stills are those which are used, and the heat applied, either by steam pipes, coiled in the interior of the still, or the lower half of the retort may be incased in an iron jacket, to which the fire is directly applied.

The spirit thus obtained is colorless, and varies in specific gravity from ·870 to ·832. A few years ago, Mr. Wildsmith obtained a patent for the februation of the spiritous and acid products of the distillation of wood. The principle of his invention is the application of an oxidizing agent, together with the influence of light, by which treatment he purposes to oxidize the carbides of hydrogen, which are unessential to the spirit and acid, but whose presence communicates a disagreeable odor to the products. Bichromate and hypermanganate of potassa are the salts generally employed, in the following manner:—The liquors are placed in a tank secluded from the air or the accidental admixture with dirt, or other impurities, by means of a cover, in which a part is glass, or some other transparent body—mica, so as to admit the light, which is necessary for the success of this application. Four ounces, avoirdupois, of the forementioned compounds, in fine powder, are used to every imperial gallon of the liquid; this may be thrown into the tank with the liquid, or the salt may be dropped into the solution gradually, and the whole well agitated. The time required to effect the purification of the spirit depends upon the quantity of tarry matters present; but, in ordinary cases, from fourteen to twenty-one days will suffice. Sunny weather favors the purification of the spirit and acid from the foreign compounds, as it brings about the combination of the oxygen of the oxidizing agent with the carbonaceous impurities in a very considerable measure. Other compounds, such as peroxide of manganese, or a properly regulated stream of chlorine gas passed through the solution, might answer the purpose, but the hypermanganate and bichromate of potassa or soda offer the greatest facilities in their use; besides, they are, by effecting the intended purpose, converted into bodies which exert no diminishing action upon the substances sought, and which may be easily separated from the spiritous and acid liquor by distillation. Chlorate of potassa might be successfully employed in the purification; it is, however, a much dearer salt than those mentioned by Wildsmith, and perhaps for that reason it is not used. When the purifying reagents have been added, the fluid should be agitated once or twice daily, in order to bring the solution of the salts into immediate contact with the impure liquor: during the intervals the cover should be kept on. Frames of glass or mica in the cover are made to slide backwards and forwards, in order to allow the liquid to be examined, and learn how far the purification has advanced. If it be desired to hasten the februation, sulphuric or hydrochloric acid is added, in the proportion of one pound of acid to fifty gallons of spirit. The object of such additions is to liberate more freely the acid in combination with the potassa, and thus bring the whole of the oxygen within reach of the carbides of hydrogen, and the other analogous impurities;

3 Eqs. of bichromate of potassa, when decomposed by
3 Eqs. of hydrochloric acid, give
3 Eqs. of chloride of potassium, while
6 Eqs. of chromic acid are liberated; thus,



The chromic acid, coming in contact with the carbide of hydrogen, gives off oxygen freely, being itself reduced to the state of sesquioxide of chromium—Cr_2O_3—thus:



When the oxidation of the impurities in the spiritous liquor is completed, it is submitted to distillation in the usual way, and a clear colorless product, without smell, and capable of being burned in lamps, or for any other required purpose, is obtained. The general yield of spirit is from one gallon and a quarter to two and a half gallons, and rarely three gallons, per the ton of wood. This variation in quantity is due often to the kind of wood carbonized, but more frequently to inattentions in regulating the proper degree of heat.

The subjoined is a tabular view of the per centage amounts of spirit in naphthas of different specific gravities, drawn up by Dr. Ure. The spirit operated upon in these experiments was purified by distillation over quicklime, at the heat of a water-bath, the temperature being so regulated that the liquid had a density of ·8136 at 60° Fahr.

Sp. gr.	Real Spirit, per cent.	Over Excise proof.	Sp. gr.	Real Spirit, per cent.	Over Excise proof.
·8136	100·00	..	·9032	68·50	13·10
8216	98·00	64·10	9060	67·56	11·40
8256	96·11	61·10	9070	66·66	9·30
8320	94·34	58·00	9116	65·00	7·10
8384	92·22	55·50	9154	63·30	4·20
8418	90·90	52·50	9184	61·73	2·10
8470	89·30	49·70			Underproof.
8514	87·72	47·40	9218	60·24	0·60
8564	86·20	46·60	9242	58·82	2·50
8596	84·75	42·20	9266	57·73	4·00
8642	83·33	39·90	9296	56·18	7·00
8674	82·00	37·10	9344	53·70	11·00
8712	80·64	35·00	9386	51·54	15·30
8742	79·36	32·70	9414	50·00	17·80
8784	78·13	30·00	9448	47·62	20·80
8820	77·00	27·90	9484	46·00	25·10
8842	75·76	26·00	9518	43·48	28·80
8876	74·63	24·30	9540	41·66	31·90
8918	73·53	22·20	9564	40·00	34·20
8930	72·46	20·60	9584	38·46	35·60
8950	71·43	18·30	9600	37·11	38·10
8984	70·42	16·16	9620	35·71	40·60
9008	69·44	15·30			

M. DEVILLE has likewise completed a table, showing the quantity of real spirit in naphtha of different specific gravities, at 48·5° Fahr.

Quantity of water.	Specific gravity.
00 per cent.	0·8070
10 "	0·8371
20 "	0·8649
30 "	0·8873
40 "	0·9072
50 "	0·9232
60 "	0·9429
70 "	0·9576
80 "	0·9709
90 "	0·9751
95 "	0·9857

The same authority says, if the above results are brought to a temperature of 60° Fahr., it will be found there is an almost complete correspondence between alcohol and wood spirit, and that the latter, equally with the former, exhibits a maximum of contraction, which always occurs on the combination of one part of wood spirit with three parts of water, *id est*, in a mixture containing 45·75 per cent. of water. URE has also constructed a table of the specific gravities of mixtures of wood spirit and water; but he has given 0·8136 as the specific gravity of anhydrous wood spirit, at a temperature of 60° Fahr. The lowest specific gravity to which pyroxylic spirit has been brought in this country, is 0·812. DUMAS, however, states that its density at the temperature of 68° is 0·798, and that of its vapor 1·120, and that its point of ebullition is 152°, at a pressure of thirty inches. MITSCHERLICH gives 0·798 as its specific gravity, and 180° Fahr. as the boiling point. SCANLAN gives 0·828 as the specific gravity, and 150° as the boiling point. The specific gravity 0·798, appears to be the correct one, as found by DUMAS and MITSCHERLICH, and from several experiments the Editor performed in Germany, its boiling point ranges between 150° and 160° Fahr.

Acetone, anesite, eupion, *et cetera*, in variable proportion in wood naphtha, cause the density to alter considerably; likewise its solvent power, as regards shell-lac, sandarac, and other resins, is materially affected by the presence or absence of such bodies. Their existence is to be attributed to the various methods of preparing the spirit, also to the want of proper care in managing the operations to which it is subjected. Pure pyroxylic spirit will not answer every purpose for which it is required in the arts. The purest, and that possessing the lowest specific gravity, is preferable for lamps as a source of heat; but for dissolving resins, and especially gum sandarac and mastic, painters and French polishers choose spirit holding some of the impurities in solution. Wood spirit of a low specific gravity, and devoid of acetone, *et cetera*, is procured by liming the raw liquor and distilling, whilst that obtained by distilling off the refined portion of the crude liquor, without saturating with the caustic earth, is an excellent menstruum for the solution of certain resins. The spirit in the former case has an incipient gravity, and is miscible with water, while in the latter it is weaker, and water renders it milky.

Pure pyroxylic spirit is sometimes used medicinally in pulmonary affections. It is readily distinguished from pyroacetic spirit by a concentrated solution of chloride of calcium, which is miscible with the wood spirit, and not with the pyroacetic spirit or acetone.

PURIFICATION OF PYROLIGNEOUS ACID, OR WOOD VINEGAR.—The purification of the acid is effected by saturating the crude liquor remaining after the spirit has been separated, with a base, evaporating to dryness and calcining the dry salt, so as to decompose the oleaginous and tarry matters present, and afterwards distilling this body with an acid—sulphuric or hydrochloric acid—and rectifying the distillate repeatedly over chloride of calcium or carbonate of soda. Lime or soda is generally employed for this purpose. The acid liquor is run off from the still into the tanks, after the naphtha has been expelled, to deposit a portion of its impurities; it is next pumped into another pan, and milk of lime, or burned lime, made into a thick paste with water, added slightly in excess, and the mixture boiled for a short time, and then run off into a vessel to rest for ten or twelve hours. During this time the excess of lime and part of the impurities combined with it precipitate, when the supernatant liquid is ready to be pumped into the evaporating pans. If the crude acid liquor is distilled before neutralizing with lime, the distillate is saturated with lime in an appropriate cistern or vat, and when the solid matters have subsided, the clear fluid is pumped into the evaporating pans. In some works the evaporators are wooden vessels, lined with lead, in which is a coil of iron piping, through which steam passes, while in others they use shallow pans of sheet-iron, having a fire beneath them. In either case the liquid is frequently stirred with a large wooden spatula, and the matters which rise to the top during evaporation are carefully skimmed off.

As the evaporation of the liquor advances, the acetate of lime crystallizes, forming a layer on the surface; this is collected with large scoops or ladles, and deposited in baskets, supported on a frame, which are directly over the pans, and thus the cooling of the drainings is prevented. The whole of the acetate of lime is thus removed, and if the crude acid be distilled previous to saturation with lime, the acetate of lime which it produces is called *grey acetate*,—if the acid be neutralized without distillation, the lime salt is called *brown acetate*. The acetate is then heated in a drying furnace at a temperature of 450° Fahr., to carbonize the resinous and other impurities. To obtain the pure acid, the grey acetate of lime is dissolved in water till the solution has a specific gravity of 1·200; filtered to separate the carbon which results from the decomposition of the tar, *et cetera;* sulphate of soda, in powder, is added, and the whole menstruum briskly agitated, to insure the complete decomposition of the lime salt. Sulphate of soda is to be added until a small portion of the liquor shows no precipitate on the addition of a concentrated solution of this salt. The quantity of crystallized sulphate of soda required to effect a complete decomposition, is about four times the weight of acetate of lime operated upon; this large amount of the decomposing body needed, is owing to the formation of a double salt, as expressed below.

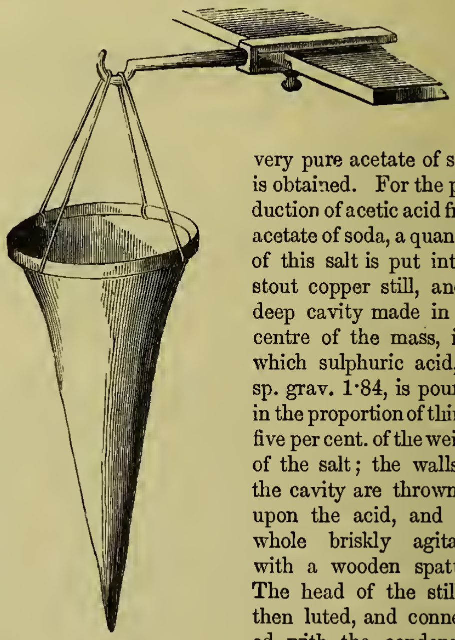
$$\underbrace{CaO, C_4H_3O_3}_{\text{Acetate of lime.}} + 2(NaO, SO_3) = \underbrace{NaO, C_4H_3O_3}_{\text{Acetate of soda.}}$$

$$+ \underbrace{CaO, SO_3, NaO, SO_3.}_{\text{Double salt.}}$$

The solution of acetate of soda, after the subsidence of the sulphate of soda and lime, is drawn off to evaporate, and the precipitate washed with water till the liquor is nearly tasteless; the washings may be retained to dissolve fresh quantities of acetate of lime. The acetate of soda liquor is concentrated in pots six feet diameter, and three feet deep, taking care to separate any impurities that may rise to the top, till it acquires a density of 1·300. If it happened that an excess of sulphate of soda had been used in the decomposition of the lime salt, it will now crystallize; it is removed by the scoops or ladles, and thrown into a wicker basket above the evaporating pans, so that the drainings may flow back to the remaining liquor without cooling. After separating the crystallized sulphate of soda, the liquor is allowed to rest for eight or ten hours, to deposit impurities—tar, *et cetera*—that are liberated during the boiling, and afterwards drawn off to the crystallizing pans, where it remains for three to five days. The crystals are then removed, and the mother liquor again concentrated to 1·300, the tarry matters removed as before, and run off to recrystallize; and so on, till the mother liquor no longer yields crystals. This liquor is evaporated to dryness, and the residue calcined; at a red heat, carbonate of soda is formed, and may be extracted by solution in water, or the brownish residue is calcined at 450° Fahr., and acetate of soda dissolved out by water. The crystals of soda salt above obtained are dissolved in fresh quantities of water, and re-evaporated till the solution is 1·500; left to repose for ten hours, the resinous bodies separated, and recrystallized at a density of 1·50: the mother liquor is treated as above detailed.

Next, the crystals are allowed to undergo the aqueous fusion at a temperature of 400°, in an iron pot, and the mass kept constantly stirred till the whole of their water of crystallization is eliminated. During this part of the operation, the greatest precautions are to be observed as to the maintaining of an even temperature—450° Fahr.—and guarding against any sparks coming into contact with the torrefying mass; this would destroy the whole of the compound, as it burns like tinder in contact with fire. A white fume rising from the liquefied salt is an indication that a part is suffering decomposition from the too elevated temperature, which should be immediately checked by throwing open the fire doors, or removing the fire altogether, if the pot be too hot. The termination of the drying is known by the subsidence of frothing, and by the fused mass presenting the appearance of an oily liquid, at which stage it is drawn off by a pipe issuing from the bottom of the pot, or it may be ladled out, allowed to cool on iron plates, and, when solidified, broken up into fragments. On dissolving this compound in twice its weight of water, filtering through bags similar to Fig. 25, and crystallizing, a very pure acetate of soda is obtained. For the production of acetic acid from acetate of soda, a quantity of this salt is put into a stout copper still, and a deep cavity made in the centre of the mass, into which sulphuric acid, of sp. grav. 1·84, is poured, in the proportion of thirty-five per cent. of the weight of the salt; the walls of the cavity are thrown in upon the acid, and the whole briskly agitated with a wooden spatula. The head of the still is then luted, and connected with the condensing worm, and the distillation carried on at a very gentle heat. The worm should be of silver or porcelain, as also the still head, and even silver solder should be used to connect the joinings in the body of the still.

Fig. 25.



In some factories it is usual to have the lower half of the still encased in an iron jacket, which receives high pressure steam, or holds oil, tallow, or fusible metal: when steam is used, the under part of the iron jacket should be furnished with a stopcock, which is turned on at intervals, to allow the condensed water to flow off; and where oil or tallow is the medium that gives heat to the boiler, a safety tube should rise, by which any oleaginous vapors are carried off if the temperature should happen to be too high. The iron jacket is placed directly over the fire in case of the oils or fusible metal being employed, and the heat given off by those substances is sufficient to distil the acid. Towards the end of the distillation, the acid passing over acquires an empyreumatic odor: as soon as this is observed the receiver must be changed, and the last portions collected in a separate vessel. An almost colorless acid, of spec. grav. 1·05, containing about forty-five per cent. of anhydrous acetic acid, passes over. The slight coloration of the acid, or any empyreuma, may be almost immediately removed by infusing with it a very small quantity of well-burnt, well-washed bone-black; or by running it off into barrels which are replenished with chips of beechwood; it will be found, in about a fortnight, to be clarified and ready for sale. Strong acid is procured by distilling the preceding acid, of spec. grav. 1·05, with fused chloride of calcium, receiving the distillate in a refrigerator; part of the acid which passes over crystallizes; the crystals are removed and dissolved in their own water, and subjected to a second rectification, as before, and this continued till the whole of the acid crystallizes at 55° Fahr.: these crystals deliquesce at the ordinary temperature, giving the acid of spec. grav. 1·063, which is a monohydrate. If the acid, spec. grav. 1·05, be required for culinary purposes, pickling, *et cetera*, it is diluted with about five times its weight of water, to render it of the same strength as revenue proof vinegar; a little caramel—burned sugar—dissolved in water, and occasionally a little acetic ether, are added, to confer a deep color, and aroma.

When the acid is required for the fabrication of the other compounds used in the arts and manufactures, where great purity is not essential, it is prepared direct from the crude lime salt by distillation with sulphuric acid. In some of the Welsh factories, the following is the mode of working:—A cast-iron cylinder, four feet long and two feet in diameter, having one end closed tightly by a stout iron door, the front end being secured by a door firmly screwed on, which may be removed at pleasure, is provided; this door is divided into two parts, the upper part being two-thirds, and the lower, one-third of the whole. In the upper division a stout iron rod passes, and runs along the length of the cylinder to the opposite end, where it is fixed in a groove. From that portion of the rod which is within the cylinder, numerous bars project at right angles, and extend through the whole concavity of the cylinder. A movable door occupies the lower division of the front of the apparatus, through which the contents of the interior are withdrawn, and the convex part of the cylinder is furnished with an opening, to which a door is screwed: the apparatus, thus completed, is termed an *agitater*. The cylinder is placed horizontally in brickwork, and the opening in the upper part affords the means by which the proper quantity of acetate of lime and sulphuric acid is introduced, in the proportion of 100 of the former to 60 of the latter. After charging the cylinder, motion is communicated to the axis passing through the upper part of the door, either by machinery or manual labor. When the contents of the agitator are completely comminuted, it is then drawn off by means of the movable door in the lower part of the front end, into a vessel placed below to receive it, out of which the half-liquid or pulpy mass is ladled into strong cast-iron trays, of three to four feet in length, two feet wide, and about two inches in depth: these trays are afterwards deposited in an oven five feet long, three wide, and the same in height, being separated from one another by iron rods laid between them, and on which they rest. A pipe passes off from the far end of this case, wherein the gaseous acetic acid flows to the condenser, which is generally a stout leaden pipe, placed in a stream of cold water. Fire is directly applied to the bottom of the oven, and continued till the whole of the acid is expelled. The crude acid that is thus procured in large quantities, is, for the most part, forwarded to London for purification from foreign bodies, such as sulphurous acid, sulphur, and traces of sulphide of hydrogen, arising from the action of the carbonaceous matters in the salt upon the sulphuric acid; resinous and tarry bodies, with a large quantity of coloring matters, also accompany the acid, and from which it is freed by redistilling with a little bichromate of potassa, or bicarbonate of soda. This second distillation is effected in leaden vessels, which are encased by a cast-iron cylinder.

The ordinary yield of acetic acid from one ton of the crude acetate of lime, when treated with twelve hundredweight of rectified sulphuric acid, spec. grav. 1·84, or fifteen hundredweight of acid of 1·77, and one ton of water, is one ton and a half of rough acid, of spec. grav. 1·05. Copper stills, or cast-iron stills with flat earthenware or tin heads, often serve for the second distillation.

To obtain acetate of lime in a sufficient state of purity, VÖLCKEL saturates the crude acid with lime, without previous distillation, whereupon a part of the resinous impurities separates in combination with lime, while the rest remains in the liquid, imparting to it a dark-brown color; the liquid is clarified by filtration, or by simply leaving the impurities to settle down, and afterwards evaporated in an iron pot to about one half its bulk. Hydrochloric acid is then added, which causes the dissolved resin to separate, and also the decomposition of the lime-compounds of creasote and other volatile substances; the former collects together in the boiling liquor, so that it can be easily skimmed, and the latter are expelled during the evaporation. The quantity of hydrochloric acid required for this purpose, varies, of course, with the constitution of the wood vinegar, which again varies with the degree of moisture of the wood from which the acid is obtained; but the weight is from four to six pounds for a hundred and fifty litres—thirty-three gallons—of the wood vinegar, or as much as will communicate a slightly acid reaction to the liquor. The solution of acetate of lime is then further evaporated, and ultimately dried at a high temperature, to expel all volatile substances. Evaporation and drying may generally be performed in the same iron vessel; but in operating on a very large scale, it is best to dry the salt on cast-iron plates: the exsiccation requires the greatest care. The volatile empyreumatic substances adhere very tenaciously to the acetate of lime, and to the resin contained in it, and unless driven off by heat they pass over in the subsequent distillation, together with the acetic acid, and impart to it a bad smell; the desiccation must, therefore, be continued till the acetate of lime becomes inodorous, or nearly so: when thoroughly dried, it has a dirty-brown color.

To procure the acetic acid, the purified lime-compound is distilled with hydrochloric acid. The distillation may be performed in a still, with copper head and leaden condensing tube. If the operation be conducted with proper care, neither copper nor lead is found in the distillate. The quantity of hydrochloric acid required cannot be exactly given, because the acetate of lime contains variable proportions of foreign matters, *videlicet*, resin, and chloride of calcium already formed. In general, however, from ninety to ninety-five parts of hydrochloric acid of spec. grav. 1·16, will completely decompose a hundred parts of acetate of lime, without causing the distillate to be much contaminated with hydrochloric acid. In any given case, the quantity of hydrochloric acid required is easily determined by an experiment on a small scale. The apparatus may likewise be so arranged as to allow of the subsequent addition of hydrochloric acid, if the quantity first used be found insufficient. Whether the amount introduced is enough, may be known by testing the distillate with nitrate of silver; so long as mere turbidity is produced, one may be sure that the hydrochloric acid is not in excess.

Distillation of the acetic acid proceeds with ease and regularity. The acetate of lime dissolves in the hydrochloric acid, forming a dark-colored liquid, while a quantity of dark resin separates. As the whole mass is liquid, the heat diffuses through it easily; and as the acetic acid passes over between 212° and 248° Fahr., and the acetate of lime has been already exposed in drying to a higher temperature, the distilled acid is but very slightly contaminated with empyreumatic products, resulting from decomposition of the resin: moreover, the resinous matters, being lighter than the chloride of calcium solution, float on the top, and do not form hard incrustations in the still.

The distilled acetic acid has but a very slight empyreumatic odor, which is also very different from that of crude wood vinegar. It is perfectly colorless, and if the hydrochloric acid has not been added in excess, gives but a slight cloud with nitrate of silver. Any yellow tint that it may exhibit, arises from particles of resin mechanically carried over; for the resin, separated from the acetate of lime by the hydrochloric acid, melts as the temperature rises, and forms a fluid layer on the surface of the chloride of calcium solution, which is very apt to cause spirting; the resin should, therefore, be removed as far as possible before distillation, either by skimming it with a spoon, or by filtration through a linen cloth. The specific gravity of the acetic acid obtained by this process, varies from 1·058 to 1·061, and it contains more than forty per cent. of anhydrous acetic acid. As, however, acetic acid of this degree of concentration is rarely used, and a somewhat weaker acid is more easily separated by distillation from the solution of chloride of calcium, it is better to add a certain quantity of water, either before or towards the end of the distillation. A good proportion is one hundred parts acetate of lime, from ninety to ninety-five of hydrochloric acid, and twenty-five of water; this gives from ninety-five to a hundred parts of acetic acid, of spec. grav. 1·015. In this manner, thirty-three gallons of wood vinegar will yield sixty pounds of acetic acid of the above strength. Acetic acid thus obtained, may be still further purified by mixing it with a small quantity of carbonate of soda, and redistilling.

The acid which passes over is free from hydrochloric acid and perfectly colorless, but still retains a slight empyreumatic odor; but this may be removed by distilling it with two or three per cent. of bichromate of potassa instead of carbonate of soda. Acetic acid purified with bichromate of potassa is, in fact, undistinguishable from that which is obtained from pure acetate of soda by distillation with sulphuric acid, or from pure acetate of lime with hydrochloric acid. It does not exhibit the slightest color when heated with strong sulphuric acid, nor does it reduce the merest trace of silver when boiled with nitrate of silver and ammonia. When saturated with oxide of lead, it yields a white salt, the analysis of which agrees perfectly with that of pure acetate of lead. Peroxide of manganese may also be used for the februation, instead of bichromate of potassa; but the acid thus purified, gives, after a while, a slight turbidity with nitrate of silver. Any empyreumatic odor that it may retain, may be removed by digestion with pure animal char coal. As the acetic acid can be easily freed from hydrochloric acid, a slight excess of the latter during distillation is not injurious; on the contrary, the presence of a small quantity of hydrochloric acid is very useful for the purification of the acetic acid, with peroxide of manganese or bichromate of potassa.

Rectification of acetic acid with bichromate of potassa, or with the peroxide of manganese, may be very well conducted in a copper still, with leaden condensing tube. The acid thus prepared can only be contaminated with a small quantity of acetate of lead. If, however, access of air be prevented during the distillation, this impurity will be confined to the first and last portions of the distillate; and by collecting these apart, to be used for the preparation of acetate of lead, the most part of the acid may be obtained free from lead. By observing these precautions, the operator may dispense with the use of glass or silver heads and condensing tubes. The entrance of air into the condensing tube may be prevented by closing the end of the tube with a cork, through which is inserted a glass tube, bent in the form ∽.

The preparation of acetic acid by the method just described, may be rendered simpler by subjecting the wood vinegar to a previous distillation, and thereby removing the greater part of the resin before forming the lime salt. But this distillation obviously entails increased expense for labor and fuel, because the same liquid must be twice evaporated; moreover, part of the acetic acid remains with the tar in the retort. On the small scale, the loss thus occasioned is unimportant. but in a large manufactory it would amount to something considerable in the course of a year.

By previous distillation of the wood vinegar, the expense may be avoided by the use of a compound still. The vapor of the wood vinegar, instead of being condensed immediately, is made to pass into a copper receiver, containing the quantity of lime required to saturate the acid, which is thereby completely absorbed. If the copper receiver be surrounded by some substance which is a slow conductor of heat, very little aqueous vapor condenses, so that it may be advantageously used to concentrate a solution of lime, resulting from a previous operation. This process is, however, more complicated, and does not yield more acetic acid than the simpler one first described.

The method here recommended is much cheaper, and yields a much purer product, than the ordinary method of distilling impure acetate of lime with sulphuric acid; further, by the addition of hydrochloric acid during the evaporation of impure acetate, the volatile slightly acid bodies contained in the wood vinegar are removed, according to SCHNEDERMANN, more easily than by the use of a solution of chloride of calcium, or by roasting the impure acetate of lime, either *per se*, or with hydrate of lime. In the latter process, even if it attains the desired end, a considerable loss is incurred from decomposition of the acetate of lime, inasmuch as that substance, from its infusibility, does not admit of any exact regulation of the heat.

Hydrochloric, instead of sulphuric acid, being used in the decomposition of the acetate of lime, has this great advantage, that the presence of resin, coloring matter, *et cetera*, in the acetate of lime, is harmless, providing the salt has been sufficiently heated to drive off these free volatile substances. When, on the contrary, sulphuric acid is used, the acetic acid produced always has a bad odor, is saturated with sulphurous acid, and contaminated by a variety of products arising from the deportment of the resins at an elevated temperature. Besides, the sulphate of lime forms a hard crust at the bottom of the retort, and in distilling on the large scale, the under part of the alembic must be heated red-hot to drive out all the acetic acid. The last portions of acid that pass over are often turbid from sulphur, and the odor of sulphide of hydrogen becomes perceptible, that gas arising from reduction of the sulphate of lime to sulphide of calcium at the bottom of the vessel; from this cause cast-iron retorts soon become corroded.

The low price at which pure acetic acid may be obtained by the method above described, will probably lead to its more extended use in dyeing and calico printing, and it may also be advantageously used in the preparation of acetates, especially of acetate of lead.

Pure Acetic Acid from Brandy Vinegar.—VÖLCKEL commends a similar process for the preparation of pure acetic acid from brandy vinegar; the process, however, is simpler, inasmuch as brandy vinegar is much less impure than wood vinegar.

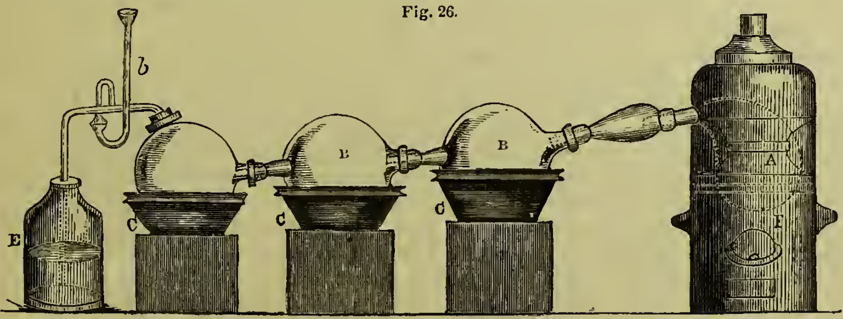
He proceeds:—Strong brandy vinegar—the best for this purpose is that which contains from twelve to fifteen parts of anhydrous acid, a proportion which is obtained in some manufactories—is saturated with lime, and the turbid and colored solution is strained through a linen cloth, and evaporated to dryness in an iron vessel. The dried salt is perfectly white, the coloring matters previously contained in the solution having been, for the most part, destroyed by the action of the air.

The decomposition of the acetate of lime is effected by hydrochloric acid, in the manner already described, excepting that the acetate of lime being less feculent than that obtained from wood vinegar, a larger proportion of hydrochloric acid is required for its decomposition, *videlicet*, about one hundred and thirty parts of acid to one hundred parts of the lime salt.

Final purification of the acid may be accomplished by either of the preceding methods.

Aromatic Vinegar.—Crystallized acetate of copper is the salt most usually employed for the preparation of this compound. Twenty pounds of the powdered acetate of copper are introduced into an earthen retort of about two gallons capacity; the retort is luted and carefully dried before applying heat for distilling off the acid, and by this precaution it lasts much longer. The elongated neck of the retort is connected with a tubulated receiver, this is joined to several others, of which the last is furnished with a curved safety-tube, dipped into a vessel of water. The retort is inserted into a furnace, and a gentle heat applied at first, which is afterwards gradually increased; the rapid or slow development of vapor serves as a guide to direct the proper application of the heat. Fig. 26 shows the apparatus on a small scale; F is the furnace which heats the retort, A; B B B are tubulated receivers, immersed in cold water in the coolers, C C C; the last receiver, B, has a WELTER'S safety tube, *b*, the long arm of which dips into the water in E, where any uncondensed vapors from the receivers are absorbed. The fire in F is lighted, and the heat gradually raised as long as any vapors pass over; if, on increasing the heat towards the end, no more vapors are given off, the distillation is terminated, the fire is withdrawn, and the apparatus allowed to cool. Twenty pounds of the copper salt produce, by distillation, about ten pounds of rough acid, of a greenish color, and 1·061 spec. grav.; the residuum in the retort consists of six and a half pounds of copper in a metallic state, mixed with a small quantity of charcoal. The crude acid is then rectified in a glass retort

Fig. 26.



of the capacity of about one gallon and a half, to which is adapted a tubulated receiver, and heat applied by means of a sand-bath. A weak acid comes over first, which is collected separately until it acquires a density of 1·072; the receiver is then changed, and the distillation continued till the condensed products begin to acquire an empyreuma, when a third receiver is supplied to collect the last portions. An acid, of spec. grav. 1·080 to 1·088, is found in the second vessel; the first and last portions are redistilled, and mixed with the stronger acid in the second receiver. The acid from twenty pounds of acetate of copper, upon a second rectification, yields six pounds of acid, spec. grav. 1·085; three pounds, spec. grav. 1·042; and half a pound of acid, spec. grav. 1·023. Other metallic acetates may be used instead of the copper salt, but with variable results as to the amount of acid which they yield. Acetates which have easily reducible oxides, as those of copper, silver, mercury, lead, *et cetera*, afford a larger proportion of acetic acid; acetone, carbonic oxide, carbonic acid, and carbide of hydrogen, are likewise evolved in greater or less proportions, and reduced metal is invariably left in the retort. The acetate of silver gives no acetone when submitted to destructive distillation. Acetates, the bases of which retain carbonic acid at a red heat, produce chiefly the carbonate of the base and acetome, but very little acetic acid: such are the acetates of potassa, soda, and baryta; and when the oxide cannot retain carbonic acid at a red heat, as is the case with the acetates of magnesia, zinc, and manganese, the acetone is accompanied by carbonic acid, and the oxides of such metals remain in the retort.

The small amount of acetone which passes over with the acetic acid, in the distillation of acetate of copper, imparts an agreeable aroma; and by the addition of a little camphor or essential oils, the *aromatic vinegar* of commerce is produced.

EXCISE DUTY ON VINEGAR.—The proof vinegar of the revenue has a spec. grav. of 1·0085, and contains about five per cent. of acetic acid. In commerce, this vinegar is represented by No. 24, from the fact that twenty-four grains of pure dry carbonate of soda are required to neutralize a fluid ounce. Weaker vinegars are represented by the Nos. 18, 20, 22, according to their strength; and, as in the foregoing instance, these figures equal the number of grains of carbonate of soda that will saturate a fluid ounce. Formerly, a duty of twopence was paid on every gallon of vinegar imported of the strength above mentioned, and if the vinegar had been double proof. a duty of fourpence was exacted. Now, however, this duty is repealed as regards the home-made vinegar, but a license of five guineas is paid by every manufacturer. The foreign vinegar imported is still subject to a duty of threepence per gallon of the revenue strength.

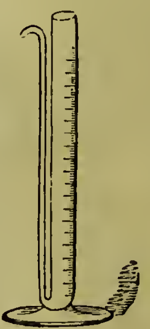
In the United Kingdom, in the year 1848, there were about fifty vinegar factories; five of these were in London, which made nearly half the whole quantity produced.

The specific gravity of vinegar is sometimes ascertained by a species of hydrometer, termed an *acetometer*. By dipping it into the vinegar under examination, and observing the depth to which it sinks, the number of the scale marking the level of the liquid indicates the density of the solution, from which, by means of a table, the per centage of real acid is ascertained.

Vinegar made from dilute alcohol, or ripe wines, in which no great excess of albuminous and other matters is present, can, to a certain limit, be tested with sufficient accuracy by the acetomer; but other vinegar, made from malt, poor wines, and such liquids as contain an excess of organic matters, do not admit of being tested with the required degree of accuracy by this method, since the foreign matters increase the density of the liquid without adding to its quantity of real acetic acid. As was shown at page 3, the specific gravity test is not to be relied on beyond a certain extent, even when an acid is produced from pure alcohol. In some cases the vinegar is saturated with chalk or milk of lime, the solution filtered, and the specific gravity of the acetate of lime liquor ascertained, by which a nearer approximation is arrived at than by the direct testing of the vinegar; yet on neither of these two methods can implicit reliance be placed. BRANDE recommends the following:—A clean dry piece of marble is weighed, and suspended by a silk thread in a known quantity of the vinegar under examination, the solution being occasionally stirred with a glass rod, without detaching any splinters from the weighed marble, till the whole of the acid is saturated, and no further action on the marble is observed. The marble is then taken out, washed with distilled water, dried, and weighed—the loss, in weight, which it has sustained, is equal to the quantity of acetic acid present, the atomic weight of carbonate of lime and dry acetic acid being nearly equal, or as 50 to 51.

The best method of ascertaining the per centage of acetic acid in vinegar, is to neutralize it with pure carbonate of potassa or soda, noting the quantity of these salts required to saturate the acid, and by finding this, the amount of real acid in a sample is ascertained by a simple calculation; for every fifty-three grains of the pure carbonate of soda, or sixty-nine grains of the carbonate of potassa—one equivalent—indicate fifty-one grains, or one equivalent, of anhydrous acetic acid. The examination is made in the following manner:—Five hundred and thirty grains of pure dry carbonate of soda are dissolved in ten thousand grains of distilled water—ten alkalimetrical measures—and this test solution kept in a stoppered bottle for use. An ounce of the vinegar is either weighed or measured, and put into a beaker or porcelain dish, and one thousand grains of the test solution—one alkalimetrical measure, equal one hundred divisions of the alkalimeter, Fig. 27—are taken and poured, in successive small portions, into the vinegar, agitating the solution well with a glass or porcelain rod after each addition. The solution is tested at intervals with blue litmus-paper, and while its color is reddened when dropped into the liquid, and the effervescing continues,

Fig. 27.



free acid is still in the menstruum, and a few drops more of test solution must be added. When the saturation of the vinegar is nearly terminated, heat is applied to expel the carbonic acid, which is absorbed, and would, if not driven off, communicate a faint rose tint to the test paper, and thus cause an error in the results. If the paper still becomes red after heating, a few drops more of the alkaline liquor are poured in, till the paper is only feebly reddened.

Sometimes a few drops of tincture of litmus are added in the beginning, and when the operation draws to a close the litmus regains in part its blue color. This, however, offers no advantage, for the acid may be completely saturated long before the color of the blue litmus makes its appearance. The number of divisions of the test liquor required to saturate the acid is read off, and by a *rule of three* calculation the amount of acid in the sample is found—for example, since five hundred and thirty grains of the alkaline carbonate, equal to ten equivalents, are contained in ten thousand grains of distilled water, one thousand grains of this solution—a hundred divisions of the alkalimeter—contain fifty-three grains, or one equivalent, of carbonate of soda, which are capable of neutralizing fifty-one grains of dry acetic acid. Now, if fifty divisions of the soda solution be added to saturate the ounce of vinegar, we find the amount of acid by the annexed proportion:—

$$\text{As } 100 : 51 :: 50 : 25{\cdot}5,$$

which is the quantity of acid present in the fluid ounce of vinegar operated upon. An ounce measure contains four hundred and thirty-seven grains, which, by the above calculation, give twenty-five and a half grains of dry acetic acid, and from this the per centage of acid is estimated:—

$$\text{As } 437 : 25{\cdot}5 :: 100 : 5{\cdot}83,$$

the real amount of acetic acid in a hundred parts of the vinegar examined. The trouble of this calculation is dispensed with by taking five hundred grains of the vinegar, instead of a fluid ounce, and adding to it the test solution as before, observing the same precautions till the acid is neutralized. A hundred divisions of the alkalimeter equal fifty-one grains of dry acetic acid; consequently, every division of the solution will neutralize 0·51 of a grain of dry acetic acid, and by multiplying the number of measures added by the factor 0·51, and dividing the product by 5, the amount is thereby obtained. Thus, if sixty measures are taken, the calculation is—

$$60 \times 0{\cdot}51 = 30{\cdot}60 \div 5 = 6{\cdot}12,$$

the per centage of acid in the vinegar.

Instead of a soda test liquor, a solution of ammonia is used to saturate the acid. This solution is prepared by adding water to concentrated ammonia till the spec. grav. is 0·992. One thousand grains of this dilute ammonia contain seventeen grains—one equivalent—of pure ammonia, which is capable of saturating fifty-one grains—one equivalent—of acetic acid The application of this test is similar to that already described. Five hundred grains of vinegar are weighed out, and the burette filled up to zero with the ammoniacal solution, which is added to the vinegar till neutralized; the calculation is the same as the preceding, that is, multiplying the number of divisions by 0·51, and dividing by 5. There is some difficulty in preserving the dilute ammonia of the same strength, which is an objection to its use; but a uniformity of concentration is insured by introducing into the bottle two glass drops, so adjusted that one remains at the bottom and the other floats just under the surface of the liquid, as long as the test liquor maintains the proper strength. If, by exposure, a part of the ammonia escapes, the specific gravity of the liquor will become proportionably greater, and the glass drops rise—the lower one higher from the bottom, and the upper one partly above the surface. When this happens, more strong ammonia is added, till the hydrostatic drops are properly readjusted.

In each of the preceding modes of testing, it is evident that, should the vinegar contain any admixture of other acids—such as sulphuric acid, hydrochloric acid, or the like—these will increase the quantity of the alkaline solution required to neutralize the weight of vinegar taken for the test; and the amount of acetic acid that results from the preceding calculation is too high in proportion to the quantity of those foreign acids. Preliminary examinations should be made to ascertain if these impurities be present, and, if so, their amount determined.

SULPHURIC ACID IN VINEGAR.—After the conversion of malt, beer, weak wines, *et cetera*, into vinegar, a putrid fermentation often takes place, which decomposes the whole of their acetic acid. It was generally considered necessary that a portion of sulphuric acid should be added, to counteract this tendency of the liquid to decomposition, and to preserve it from turbidity. This addition was permitted to the extent of one gallon of sulphuric acid to one thousand gallons of vinegar, by an Excise regulation, and had, therefore, a legal sanction; but sulphuric acid is now known to be unnecessary in properly prepared vinegars, although still added by some manufacturers for the purpose of increasing the strength of their vinegars, or, in some instances, merely from habit and the indisposition to disturb the routine of an old-established practice. Sulphuric acid in vinegar should be looked upon as a mark of inferior quality; for it is only where the mode of manufacture is defective, that the addition appears to be at all necessary. The seemingly small admixture of one part of sulphuric acid in a thousand of vinegar, cannot be viewed directly as a source of internal injury to the consumer; nevertheless, it does not in the least favor digestion, and it is known that, in larger quantities, it affects the coats of the stomach. Besides the addition of the one-thousandth part of sulphuric acid, many persons—makers or venders—add a far greater proportion, in order to confer that acidity which ought only to be produced by the acetic acid. Some of these admixtures are most dangerous to the community, as often the commonest oil of vitriol is used as the adulterant. The Editor had, not long since, an opportunity of examining a sample of vinegar, and found it contained arsenic, a fact which he attributes to the use of common pyrites vitriol.

Several methods have been given in chemical books for the detection of sulphuric acid in vinegar or acetic acid, some of which cannot be applied unless the sulphuric acid be present in such proportion as would make the most reckless shrink from sending the fabrication into the market. Here will be enumerated a few of the more trustworthy for the qualitative and quantitative estimation of sulphuric acid in vinegars. It should, however, be borne in mind, that vinegar made from wine, malt, *et cetera*, contains some soluble neutral sulphates, these being natural constituents of the grain or grapes from which the wine or fermented wort is obtained; and that, by the more delicate tests, this quantity of sulphuric acid in combination will be indicated.

The most fastidious against adulterations cannot object to the presence of these minute portions of soluble sulphates, since the small amount of acid in the salts is chemically united with a base, and therefore cannot injuriously affect the animal organism. If the vinegar be suspected to contain a greater quantity of sulphuric acid than authorized, it may be ascertained pretty accurately by making a solution of sugar in thirty parts of water, bringing the liquid to a temperature of 190° or 200° Fahr., by means of steam heat; if a drop of the suspected vinegar be added, it will carbonize the sugar, causing a blackish spot to appear at the point where the vinegar came in contact with the saccharine solution. This happens when the vinegar contains the one three-hundredth of its weight of the adulterant; and when the amount ranges between the one six-hundredth and one eight-hundredth of the impurity, a greenish spot appears.

The next and principal test is the precipitation of the sulphuric acid by means of a soluble salt of baryta, in the form of insoluble sulphate of baryta, which falls down as a heavy white powder. Judging from the bulk of the precipitate obtained from a certain quantity of the vinegar, a tolerable inference may be drawn as to the fact of the vinegar containing more than the ordinary amount of sulphuric acid. When only about the eight-hundredth or one-thousandth of the adulterant is present, an immediate white precipitate indicates the presence of sulphuric acid; but this precipitate does not so quickly subside as when larger quantities are present.

For the quantitative determination of sulphuric acid, the best way to proceed is the following:—Half a pound of the vinegar is weighed and evaporated in a porcelain or platinum basin, on a water-bath or by steam heat, till the eight ounces are reduced to one ounce; the basin is then removed from the heat and allowed to cool, and five or six times its bulk of strong spirit of wine or alcohol added, in which the earthy and alkaline sulphates naturally present in the vinegar are insoluble, and consequently fall down. After the precipitate has subsided, the solution is filtered off, and the residue edulcorated twice with dilute spirit. The most part of the alcohol is expelled by evaporation in the water-bath, and the remaining liquid diluted with ten or twelve times the volume of water, and afterwards a solution of chloride of barium poured in as long as a precipitate is formed. The precipitate, after subsidence and filtration of the supernatant liquid, is digested with moderately dilute warm hydrochloric acid, then thrown upon a filter, washed with boiling water till a portion of the washings gives no white precipitate upon addition of sulphuric acid, dried in a water or air bath, and, when dry, burned in a platinum crucible. When accurate results are desired, the precipitate should be detached as much as possible from the filter-paper, and the latter burned in the crucible until the whole of the carbonaceous matter of the paper is destroyed, and the precipitate then introduced, heated to redness, and weighed. Every hundred and sixteen and a half parts of this precipitate indicate forty-nine parts of monohydrated sulphuric acid.

When great accuracy is not required, a solution of chloride of barium is made, of standard strength, by dissolving one hundred and twenty-two grains of the crystallized salt in two thousand grains of distilled water; five hundred grains of vinegar, diluted with twice its weight of water, are poured into a tall and not very wide beaker glass, or precipitating jar; one hundred alkalimetrical divisions are taken and poured gradually from the burette, in small portions at a time, into the vinegar, stirring well after each addition with a glass rod, and then leaving the whole to rest in a warm situation till the precipitate collects at the bottom, after which another addition of the test solution is made, observing the same rule as above given, as long as any precipitate forms. When the last drop causes no precipitate, or, at least, only a very slight one, the number of measures of test solution added are read off, and from this the amount of sulphuric acid is calculated. Since the one hundred and twenty-two grains of the salt—one equivalent—correspond with forty-nine grains of rectified sulphuric acid. and that this quantity is contained in the two thousand grains of liquid, half this solution will contain sixty-one grains of the baryta salt, which quantity equals twenty-four and a half grains of monohydrated sulphuric acid. If fifty measures of the test solution be added to the five hundred grains of vinegar, the per centage of acid is found by multiplying the number of measures, or fifty, by twenty-four and a half, and dividing this product by five hundred; thus—

$$50 \times 24{\cdot}5 = 1225{\cdot}0 \div 500 = 2{\cdot}45 \text{ per cent.};$$

from which 0·1 per cent. should be deducted for the addition allowed by government. Some waters contain a large quantity of sulphates, by which a greater amount of the test solution is required to throw down the entire sulphuric acid, free and combined; but if it be suspected that this is the case, the examination of the water employed should precede the testing of the vinegar, or the analysis should be conducted as indicated in the foregoing, namely, evaporation of the vinegar, and treatment with alcohol, *et cetera.*

HYDROCHLORIC ACID IN VINEGAR.—This acid is not so frequently met with in vinegar as sulphuric acid; indeed, the sophisticator rarely has recourse to it. Its presence may be ascertained by distilling a quantity of the vinegar from a glass retort, to which a condenser is attached, and adding a few drops of a solution of nitrate of silver to the distillate. A white precipitate indicates the presence of hydrochloric acid.

To determine, quantitatively, the amount of the acid, eight or sixteen ounces of the vinegar are distilled, as just mentioned, care being taken not to lose any either in its introduction into the retort or otherwise, till the whole of the liquid has passed over into the receiver. A solution of nitrate of silver is poured into the distillate as long as a precipitate occurs. The solution is left at rest till the white curdy precipitate of chloride of silver falls to the bottom, which is filtered off, washed with a little dilute nitric acid first, and afterwards with distilled water; dried at 212° in a water-bath, ignited in a porcelain crucible, and weighed. From the weight of the chloride of silver, that of the hydrochloric acid is calculated.

A hundred and forty-three and a half parts of chloride of silver are equal to thirty-six and a half parts of dry hydrochloric acid, or one hundred parts of liquid hydrochloric acid of spec. grav. 1·180. If the weight of chloride of silver, from the eight ounces, be sixty grains, the per centage is found as follows:—

$$143{\cdot}5 : 36{\cdot}5 :: 60 : 20{\cdot}34,$$

the amount of acid in the eight ounces of liquid taken; and by multiplying these ounces by four hundred and thirty-seven and a half, the number of grains in a fluid ounce, the number of grains weight operated upon are obtained; thus—

$$437{\cdot}5 \times 8 = 35000 : 20{\cdot}34 :: 100 : 0{\cdot}581$$

per cent. of dry hydrochloric acid.

NITRIC ACID IN VINEGAR.—This acid is rarely employed to adulterate vinegar. If it be suspected, the application of the following test will corroborate or remove the suspicion:—About eight ounces are neutralized with carbonate of soda, the liquid evaporated to dryness, and the residue distilled with a few drops of strong sulphuric acid. The distillate is received in an ice-cold receiver, neutralized with potassa, and a solution of starch paste and iodide of potassium added. If a blue compound—iodide of starch—forms, it is an infallible proof of the presence of nitric acid: a simpler test is to boil a portion of the residue from the preceding with hydrochloric acid and copper turnings; if nitric acid be present, red fumes of nitrous acid, possessing a very characteristic odor, are evolved.

TARTARIC ACID IN VINEGAR.—By evaporating a portion of the vinegar in a water bath, if tartaric acid be present, a viscid mass of the consistence of treacle, and highly acid, remains. On adding alcohol to this substance, and agitating for a short time, the tartaric acid is dissolved; the spiritous extract filtered off, mixed with chloride of potassium, and well agitated, yields a crystalline precipitate of bitartrate of potassa—cream of tartar—in the presence of tartaric acid. It must be remarked that wine vinegar naturally contains some tartaric acid in the form of cream of tartar—this compound being one of the solid constituents of the grapes.

METALLIC SALTS IN VINEGAR.—The salts which are formed in vinegar arise from the action of the acid on the metallic vessels employed. Vinegar made by the *quick* process, or in *vinegar fields*, never contains any of these compounds, except the vinegar is afterwards distilled in metallic vessels; the acid at a high temperature, with an excess of air, acts on the metallic substances of the still or condensing worm. As copper, lead, tin, and zinc, are generally the materials used in the construction of the still or worm, these are the only bodies that have to be looked for in the vinegar. A portion of the vinegar is submitted to a stream of sulphide of hydrogen gas; if a black color or precipitate be produced, copper or lead is present. Another portion, ten ounces, of the vinegar is evaporated to dryness in a basin, and the residue heated to redness in a porcelain crucible, and the whitish ash remaining treated with a few drops of nitric acid, heated, and filtered; if, on treating the solution with ammonia, a more or less blue color is given to the liquid, copper is present. Tin gives a yellow coloration with sulphide of hydrogen. The latter has no action upon zinc; but on the addition of ammonia, or sulphide of ammonium, a white precipitate is formed—a small proportion of iron is sufficient to give a greyish or blackish color to the precipitate. The quantity of salts found in vinegar is generally so very small as not to be detected by the tyro unless a large quantity of the vinegar is evaporated, and the residue submitted to a thorough chemical examination.

Should pepper, chillies, *et cetera*, be added to vinegar for the purpose of conferring more pungency, they may be detected by neutralizing the acid with carbonate of soda, and tasting the liquid; if these bodies be present, the solution will still retain the sharpness peculiar to such spices.

Flies—*musca cellaris*—and eels—*vibrio aceti*—are often found in vinegar; they may be destroyed by passing the vinegar through tubes immersed in boiling water.

The average per centage of fixed matter which remains after evaporating the different vinegars to dryness, is as follows:—

Wine Vinegar,	2·05 to 2·10
Beer Vinegar,	5·00 to 6·00
Cider Vinegar,	1·40 to 1·50

Vinegar, as a condiment, serves admirably for promoting digestion. It exerts a solvent action on the albuminous and proteine compounds of the food; hence the reason of its being constantly served with salads, fish, veal, and other substances rich in such matters. Its free use, however, should be avoided.

Acetic acid is also extensively employed to preserve animal and vegetal substances liable to decay or putrefaction. Wood vinegar is preferable to other varieties, on account of the small quantities of essential oils which it contains, and which render its antiseptic properties more active. The creasote of this acid confers a smoky taste on meats. Vinegar is sometimes concentrated by exposing it to cold, and separating the layers of ice; although the greater part of the water is by this treatment removed, yet a large quantity of acetic acid is likewise abstracted, and where the vinegar is very dilute, the process is not at all economical. Another method is, to keep the vinegar heated at a temperature between 212° and 220° Fahr.; for, while water boils at 212°, the hydrated acetic acid boils at 248°, so that at 212° a large proportion of water is driven off and very little acid; every disadvantage is removed when the boiling point of the vinegar is elevated. STEIN recommends for this purpose the addition of chloride of sodium, in the proportion of thirty pounds for every hundred pounds of vinegar. The acid then distils over without loss, and is obtained much stronger than in the ordinary mode of distillation.

Some cautions may here be given with reference to the vessels in which vinegar is kept, as these often consist of metals. A painted vessel should never be used, the basis of nearly all pigments being white lead, which readily dissolves in acetic acid, forming sugar of lead—acetate of lead; and many paints contain copper and other metallic substances, soluble in acetic acid, all of which may prove poisonous. Copper vessels may be employed with safety, provided the inner surface be kept bright, and the acid be not suffered to remain in them after cooling. Iron is too easily attacked by the acetic acid to be used; and although the salt which is formed in the liquid—the acetate of iron—is not injurious in small quantity, yet it communicates to food a disagreeable styptic taste.

Common earthen vessels, glazed with oxide of lead—litharge, red lead—part of which is frequently uncombined with the body of the ware, should not be employed; for the acid would undoubtedly dissolve that portion of the oxide, and might even attack the well-burned porcelain itself—the more so if the acid be heated in the vessel. Salt-glazed stoneware, good English pottery, porcelain, glazed or enamelled iron, silver, and copper—under the above precautions—may all be employed for boiling acetic acid or its preparations with safety.

Acetic acid is employed to a large extent in the arts, chiefly in calico-printing and dyeing. When required for these uses, it is united to bases, with which it forms acetates, principally used as mordants. It is likewise used in the preparation of varnishes; for dissolving gums and albuminous bodies. Aromatic vinegar is medicinally applied as a stimulant against fainting, and externally as a rubefacient.

STATISTICS OF THE VINEGAR MANUFACTURE.—The total number of vinegar makers—not including pyroligneous acid—in the United Kingdom, in 1844, was forty-four. The quantity of vinegar made between the fifth of July, 1843, and the fourth of July, 1844, was 2,828,043 gallons, on which a duty of £24,745. 7s. 6d. had been paid. At present there are about fifty manufacturers who make over 3,000,000 gallons annually; of these the five principal ones are in London, and they make nearly half the entire quantity.

The following table exhibits, under the respective years, the number of vinegar factories in the United Kingdom, during the six years ending with 1846:—

1841.	1842.	1843.	1844.	1845.	1846.
58	59	54	44	60	56

which paid, at the rate of five guineas license fee, the undermentioned sums, namely:

1841.	1842.	1843.	1844.	1845.	1846.
£304. 10s.	£309. 15s.	£283. 10s.	£231	£315	£294

The number of gallons produced by the home factories during the period previous to the repeal of the vinegar duty, was, in

	1841.	1842.	1843.
Gallons,	3,102,098	3,175,722	2,993,061
Duty,	£27,143. 7s. 1d.	£27,787. 11s. 3¼d.	£26,189. 5s. 7½d.

	1844.	1845.	1846.
Gallons,	2,828,043	—	—
Duty,	£24,745. 5s. 7d.	—	—

From the year 1844, the duty on the home-made was repealed, but a levy of fourpence-halfpenny per gallon of proof strength is paid by that which is imported from foreign countries, of which more or less is received every year. The annexed tables show the number of gallons of foreign vinegar imported into Great Britain during the foregoing period, and chargeable with duty:—

Number of gallons chargeable with duty imported in

1841.	1842.	1843.	1844.	1845.	1846.
53,695	41,311	21,784	88,722	95,967	63,821;

and the quantity retained for home consumption, and chargeable with duty, was, in

1841.	1842.	1843.	1844.	1845.	1846.
Gls.	Gls.	Gls.	Gls.	Gls.	Gls.
22,205	18,139	14,143	63,029	74,236	73,079

During the corresponding four months, ending the 4th of May, of

	1844.	1845.	1846.	1847.
	Gls.	Gls.	Gls.	Gls.
There were entered at the port of London chargeable with duty,	6,360	2,378	6,612	2,677
Of which there were retained for home consumption under duty,	3,465	1,563	4,326	1,966

The number of gallons imported during the three years ending the 5th of January, 1852, was

Year.	Quantities imported into the United Kingdom.	Quantities admitted for Home Consumption.	Amount of duty received thereon.
1850	63,929 proof gallons.	52,697 proof gallons.	£927
1851	87,911 "	69,667 "	1,240
1852	109,168 "	69,897 "	1,221

SESQUIACETATE OF ALUMINA.—*Red Liquor.*—This salt is extensively used by calico-printers, as a mordant of a very superior quality. It may be prepared for laboratory purposes by decomposing a solution of sulphate of alumina by acetate of baryta. Sulphate of baryta and acetate of alumina are formed; the former falls down as a heavy white insoluble powder, and the supernatant liquid contains the acetate of alumina. The decomposition which takes place is represented in the following equation:—

$$\underbrace{Al_2\,O_3,\,3\,S\,O_3}_{\text{Sesquisulphate of alumina.}} + 3\,\underbrace{(Ba\,O,\,C_4\,H_3\,O_3)}_{\text{Acetate of baryta.}} = \underbrace{Al_2\,O_3,\,3\,C_4\,H_3\,O_3}_{\text{Sesquiacetate of alumina.}}$$

$$+\,3\,\underbrace{(Ba\,O,\,S\,O_3)}_{\text{Sulphate of baryta.}}.$$

On evaporating the liquor filtered from the sulphate of baryta to dryness on the water-bath, the salt is obtained in the form of a gummy mass, which is very soluble in water and deliquescent, and parts with its acid at a slightly elevated temperature, leaving a subacetate, and at a red heat pure alumina. The dry mass has the following composition:—

	At. weight.		Per centage weight.
1 Eq. of alumina,..................	52	=	25·366
3 Eqs. of acetic acid,..............	153	=	74·634
1 Eq. of sesquiacetate of alumina,..	205	=	100·000

Formula:—$Al_2 O_3, 3 C_4 H_3 O_3$.

Commercial sesquiacetate of alumina—*red liquor*, from its being colored with lichens—is always met with in the liquid state. It is manufactured for the use of calico-printers, by adding to every gallon of acetate of lime liquor, 2⅝ pounds of alum, agitating the mixture briskly, and then leaving it to rest, in order that the sulphate of lime may settle down. The decomposition of the acetate of lime is known by testing a small portion of the filtered liquid in a tube with a concentrated solution of alum; if a precipitate of sulphate of lime falls, more alum must be added, till the acetate of lime is completely decomposed. The liquor is now filtered off, and the solution concentrated by evaporation till it acquires a spec. grav. of 1·087 to 1·100; allowed to repose for some time to deposit any sulphate of lime, and then drawn off for use or for market. The quality of this liquid as a mordant is inferior, on account of the partly imperfect decomposition of the lime salt, and of the presence of a small portion of lime still retained in the red liquor, which impairs very much the beauty and gloss of the color given to the cloth.

A better mordant is made by decomposing alum by acetate of lead. Since the sulphate of lead is insoluble, the decomposition of the alum solution is more perfect than when acted upon by acetate of lime; still, the red liquor is not a true acetate, but a mixture of acetate and subsulphate of alumina with hydrate of alumina and sulphate of potassa, as will be seen from the recipes in general use for its manufacture. Were an equivalent of sulphate of alumina decomposed by corresponding three equivalents of acetate of lead, a sesquiacetate of alumina would result; in practice, however, it is found more advantageous to employ equal parts of alum and sugar of lead, or rather a less quantity of the latter. The alum is dissolved in boiling water, and the powdered acetate of lead added to the solution. About one-tenth of crystallized carbonate of soda, or a little carbonate of lime, is added to the alum, to combine with the free acid. The three following recipes serve to indicate the proportions employed:—

No. 1.—Dissolve 100 lbs. of alum in 50 galls. of boiling water, and add 100 lbs. of acetate of lead in fine powder, stirring the mixture well at first, and likewise several times during the cooling.

The clear supernatant liquid consists of an acetate of alumina, sulphate of potassa, and a little subsulphate of alumina.

No. 2.—Dissolve 100 lbs. of alum in 50 galls. of water; to the solution add slowly 10 lbs. of crystallized carbonate of soda, and then stir in 100 lbs. of acetate of lead in powder.

No. 3.—Dissolve 100 lbs. of alum in 50 galls. of boiling water, and add in small portions 6 lbs. of crystallized carbonate of soda, and then stir in 50 lbs. of acetate of lead in powder, as before.

Nos. 2 and 3 contain acid acetate of alumina, basic sulphate of alumina dissolved in acetic acid, and sulphates of potassa and soda. No. 2 becomes cloudy at 154° Fahr., and gelatinizes at 165°; No. 3 clouds at 176°, and gelatinizes at 192°; the cloudiness disappears on cooling, and is entirely prevented by an excess of alumina in the solutions. According to certain experiments, it appears that the activity of the red liquor is not wholly dependent upon the amount of acetate of alumina which it contains, as a portion of the salt is converted into a basic sulphate which combines with sesquiacetate of alumina; on basing the goods in this solution and drying, a portion of the basic acetate combines with the basic sulphate of alumina; and on subsequently submitting the goods to the drying-bath, acetic acid is partly volatilized, and the aluminous basic compound remains perfectly combined with the cloth.

Further, it is shown that it is immaterial, as to the effect on the texture, and the beauty of color produced on the cloth, whether one hundred pounds of alum be decomposed by one hundred and twenty-five, or seventy-five pounds of acetate of lead, since the acetate of alumina acts by giving up its base to the fibre of the cloth, and that this is effected as well when a basic sulphate of the earth is present as when it is wholly in the form of a sesquiacetate. Runge has made some experiments, by which he shows that the quantity of acetate of lead should be always one hundred and twenty pounds to every hundred pounds of alum, and that even the amount of water employed affects the quality of the product. He based equal weights of cotton fabric in each of the following solutions, made by adding—

100 lbs. of alum,
75 lbs. of acetate of lead, and
280 lbs. of water together, agitating the mixture, and filtering:

Secondly, by dissolving—

100 lbs. of alum in
448 lbs. of water, and adding
120 lbs. of acetate of lead in powder, agitating the mixture, and filtering off the clear liquor, as above.

The fabrics being allowed to remain in an equal measure of these solutions for the same time, and dried at the same temperature, were washed with equal quantities of hot water; the washings from the cloth mordanted in the first solution contained much alumina, while only very slight traces were indicated by the washings from the cloth steeped in the second solution. The usual addition of carbonate of soda, to the extent of about one-tenth of the alum employed, acts advantageously in the manufacture of red liquor, where a low proportion of sugar of lead is used, by uniting partly with the sulphuric acid, and producing a basic sulphate, as well as acetate of alumina, as mentioned above.

However, it appears, from practical observations, that a sulphoacetate of alumina is to be preferred, as giving the most satisfactory results. Mr. Calvert states, that a mordant of the composition—

$$Al_2 O_S \begin{cases} S O_3 \\ 2 C_4 H_S O_3, \end{cases}$$

is the best adapted for fixing the colors, on account of the excess of alumina in such a solution above those which contain, besides the aluminous salts, salts of the alkalies, which are inert in the uses for which red liquor is manufactured.

The preceding he prepares by mixing together—

453 lbs. of ammonia alum,
379 lbs. of acetate of lead, and
1132 lbs. of water;

or,

383 lbs. of sulphate of alumina,
379 lbs. of acetate of lead, and
1132 lbs. of water;

or,

453 lbs. of alum, and a quantity of solution of acetate of lime, amounting to one hundred and fifty-eight pounds;

or,

333 lbs. of sulphate of alumina, with the same amount of acetate of lime solution.

On agitating the foregoing mixtures, decomposition takes place; sulphate of lead or of lime is thrown down, and a sulphoacetate remains, with an equivalent of sulphate of ammonia from the ammonia alum. Instead of alum, many printers now use sesquisulphate of alumina in the fabrication of this mordant, which is much more economical, as the solution of this salt, brought to the standard strength, or 1·085 spec. grav., contains more alumina than the ordinary red liquor of that strength, as the following analyses show:—

COMPOSITION OF FOUR MORDANTS PER GALLON.

	Formula. $Al_2O_3, SO_3, 2 C_4H_3O_3 + NH_4O, SO_3$.		Formula. $Al_2O_3, SO_3, C_4H_3O_3 + NH_4O, SO_3$.	Formula. $Al_2O_3, SO_3, 2 C_4H_3O_3$.
	Mordant **A.**	Mordant **B.**	Mordant **C.**	Mordant **D.**
	Grs. Oz. Grs.	Grs. Oz. Grs.	Grs. Oz. Grs.	Grs. Oz. Grs.
Alumina,	1680·0 = 3 368	1830·0 = 4 80	1239·0 = 2 365	2164·4 = 4 414
Acetic acid,	3369·8 = 7 307	3570·0 = 8 170	1281·7 = 2 406	3679·2 = 8 179
Sulphuric acid,	2642·5 = 6 17	2800·0 = 6 175	3017·0 = 6 392	1664·6 = 3 352
Ammonia and water,	674·1 = 1 236	910·0 = 2 35	653·1 = 1 215	

ACETATE OF AMMONIA—*Spirit of Mindererus*—in solution, is obtained by saturating distilled vinegar with carbonate of ammonia; this salt constitutes the *liquor ammoniæ acetatis* of the *Pharmacopeia*, which has long been used in medicine as a diaphoretic. When equal weights of chloride of ammonium and acetate of potassa are distilled together, at an incipient temperature ammonia is at first eliminated, and afterwards binacetate of ammonia distils over, in the form of an oily liquid— $\underbrace{2 (NH_4Cl)}_{\text{Chloride of ammonium.}} + \underbrace{2 (KO, C_4H_3O_3)}_{\text{Acetate of potassa.}} = \underbrace{NH_4O}_{\text{Ammonia.}} + \underbrace{(NH_4O, 2 C_4H_3O_3)}_{\text{Binacetate.}}$ —which concretes into acicular crystals, deliquescent, and dissolved in all proportions by water and alcohol. Dry ammonia, transmitted into the fused binacetate, converts it into the solid neutral acetate; a white inodorous salt, easily soluble in water and alcohol, and converted by heat into ammonia and the binacetate of ammonia—

$$\underbrace{NH_4O, C_4H_3O_3, HO, C_4H_3O_3}_{\text{Binacetate of ammonia.}} + \underbrace{NH_4O}_{\text{Ammonia.}} = \underbrace{2 (NH_4O, C_4H_3O_3)}_{\text{Neutral acetate.}} + HO.$$

Binacetate of ammonia forms striated prisms, fusible at 168°, and subliming unchanged at 248°.

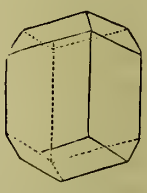
The neutral acetate of ammonia has the composition:—

	Atomic weight.	Centesimally represented.
1 Eq. of acetic acid,	51·00	38·93
1 Eq. of oxide of ammonium,	26·00	19·84
6 Eqs. of water,	54·00	41·23
	131·00	100·00

Formula:—$NH_4O, C_4H_3O_3 + 6$ aq.

ACETATE OF COPPER.—There are several acetates of copper, one of which is of the suboxide, the others being of the protoxide of copper. Of the latter, the most important in the arts are the neutral acetate of copper, the bibasic acetate—*verdigris*—and the tribasic acetate of copper. The neutral acetate of copper is formed by dissolving the hydrated oxide of copper in acetic acid, or by precipitating a solution of sulphate of copper by acetate of lead or baryta, filtering off the precipitated sulphate of lead or baryta, and evaporating the filtered liquid, and crystallizing. The crystals are in oblique rhombic prisms—Fig. 28—of a dark-green color, and possess a disagreeable metallic taste; soluble in about thirteen and a half parts of cold, and five of boiling water. The composition of the neutral acetate is:—

Fig. 28.



	Atomic weight.	Per centage quantity.
1 Eq. of oxide of copper,	40	40·00
1 Eq. of acetic acid,	51	51·00
1 Eq. of water,	9	9·00
	100	100·00

Formula:—$CuO, C_4H_3O_3 + HO$.

Acetate of copper was formerly employed in the manufacture of acetic acid. The suboxide of copper is obtained in red octahedral crystals when the neutral salt is heated with organic substances, such as sugar, honey, starch, *et cetera.*

When the commercial verdigris is dissolved in dilute acetic acid, and the salt crystallized at 40° to 45° Fahr., an acetate with five atoms of water is obtained, in beautiful blue oblique four-sided prisms. On raising the temperature to about 86°, the crystals almost instantaneously lose their blue color, and acquire a greenish hue; four atoms of water are expelled, and neutral acetate remains, with one atom of water.

Its chief use in the arts is in making pigments, and for resisting the blue color which the indigo would communicate in the indigo-bath of the calico-printer.

In the latter case, its mode of action depends on the readiness with which it parts with oxygen, whereby the indigo is oxidized before it can exert any action on the cloth, being itself reduced to the state of acetate of suboxide of copper. Verdigris is occasionally employed as a transparent green water-color or wash for tinting maps.

Bibasic Acetate of Copper.—*Verdigris; Ærugo.*—This salt is formed by exposing thin copper plates, in a confined space, to the combined action of air and moisture, or by submitting copper plates to the action of fermenting *marcs*—refuse from the wine factories; in the course of a few days, a coating of subacetate forms on the plates, which may be scraped off, and the remaining part of the plate submitted to a fresh operation, till all the copper is converted into verdigris.

The manufacture of verdigris on the large scale is conducted as follows:—In France, the chief seats of this manufacture are at Grenoble and Montpellier, where the operations are conducted in a rude but effective way, and usually by women. Husks and refuse of grapes from the wine factories, not entirely exhausted of their juice, are spread loosely in casks until the acetous fermentation takes place. The casks or vessels are covered with matting, to protect them from dirt. The limit to which fermentation of the marcs should be carried, is known by introducing a test sheet of copper into the mass for twenty-four hours; if, on withdrawing it at the end of that time, it is found covered with a uniform green coating, the proper degree of fermentation is reached, otherwise the mass is allowed to remain a day or two longer. Alternate layers of sheets of copper of one twenty-fourth of an inch thick, and the fermented marcs, are introduced into large casks, observing that the top and bottom layers are of the latter.

Sheets of copper are prepared by hammering bars of the metal to the above thickness—the more compact the copper sheets, the better—and they are then cut out into pieces of six or eight inches long by three to four broad. These plates are immersed in a concentrated solution of the verdigris, and dried over a charcoal fire; then heated to about 200° Fahr., being held by a cloth in the hand, and packed in the vessels with layers of the fermented husks, as above-mentioned. If the plates be not immersed in the solution of the acetate before packing in the casks with the fermented stalks and skins of the grape, they are liable to be covered with a black coating, instead of the green acetate. The quantity of metal required to fill each vessel is between thirty and forty pounds. Twenty days are sufficient to complete the corrosion of the copper sheets, and induce their combination with the acetic acid present in the marcs, but often sixteen or twelve days perfect the work. After this period, the upper layer of marcs will appear whitish, and if the whole has worked favorably, the plates will be covered with silky crystals of a green color. The plates are then taken from the casks, and dried in the air for two or three days, after which they are moistened with water and again placed to dry, by laying them upright against each other for a week. This process of moistening with water is continued at regular intervals of a week, for six or eight times. By this mode of operation, the plates swell and become encrusted with increasing coatings of the copper salt, which are detached from the remainder of the plates by a copper knife. The scraped plates are submitted to a fresh treatment, till the whole of the copper is converted into verdigris. After scraping off the salt, it is made into a thick consistent mass by kneading it with a little water, and in this state it is packed into leathern bags, which are placed in the sun to dry, until the mass hardens and forms a tough substance like the commercial article.

At Grenoble the process is nearly the same as above, excepting, that instead of moistening the plates with a solution of subacetate of copper, they employ acetic acid. In Germany, Sweden, and England, the manufacture is somewhat different from the preceding, inasmuch as, instead of the fermented marcs of the grapes, woollen cloths steeped in pyroligneous acid are used, which are placed alternately with the copper plates in a square wooden box. The cloths are moistened with acetic acid every three days for twelve or fifteen days, till small crystals begin to form on the plates. When this happens the cloths are partly withdrawn, and a space allowed for the circulation of the air, the whole being moistened weekly with water. Generally, five or six weeks elapse before the completion of the work.

Acetate of copper is likewise made by acting upon thin sheets of copper, in small vessels, with acetic acid. The copper is not immersed in the acid, but nearly touches its surface; a temperature of about 150° to 180° Fahr. is maintained during the operation. The plates become, in time, coated with acetate, as in the forementioned processes, which is scraped off and dried for the market.

The composition of pure verdigris is:

	Atomic weight.	Containing centesimally.
2 Eqs. of oxide of copper,	80	43·24
1 Eq. of acetic acid,	51	27·57
6 Eqs. of water,	54	29·19
1 Eq. of bibasic acetate of copper,	185	100·00

which, on comparison with the analysis of the best French and English manufacture, tells in favor of the latter.

	Theory.	French Verdigris, centesimally represented.	English Verdigris, centesimally represented.
Oxide of copper,	43·24	43·50	44·25
Acetic acid,	27·54	29·30	29·62
Water,	29·19	25·20	25·51
Impurities,	—	2·00	0·62
	100·00	100·00	100·00

Formula:—$2\,CuO,\ C_4H_3O_3 + 6\,HO$.

This salt is often employed in painting, and likewise in calico-printing, for precisely the same purpose as the neutral acetate; namely, as a resist paste in the indigo dye-bath.

Good verdigris should be dry, have a fine bluish-green color, and be soluble in dilute acetic and sulphuric acids, and also in ammonia.

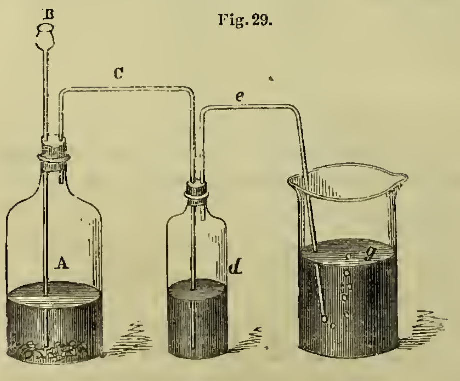
Verdigris is often adulterated, generally with finely ground pumice, chalk, and sulphate of copper. The purchasers acquainted with this article judge of the relative purity of the sample from its bright color, and by kneading it on the palm of the hand with a little water; by the latter test the presence of sand is detected, as the subacetate alone should form a paste free from any grittiness.

For the detection of chalk—carbonate of lime—a weighed portion of the verdigris, in powder, is introduced into a flask, and hydrochloric acid poured upon it; if effervescence takes place, it indicates the presence of carbonates; should, however, no effervescence occur, and, at the same time, a residue of silica remains undissolved, it shows that pumice, or some analogous body, is the adulterant; the residue is greater or less in proportion to the extent of adulteration.

If the hydrochloric acid solution of the above be filtered off, and the residue, being well washed, dried in a water-bath at 212°, and afterwards burned in a weighed platinum crucible till the whole of the charcoal of the paper is consumed, and weighed—the increase of weight will give the amount of insoluble impurities in the sample. On adding chloride of barium to the filtered liquid and washings, a white insoluble precipitate of sulphate of baryta will fall down, if sulphates of copper or iron be present. By placing the beaker on the hot sand-bath the precipitate quickly settles down, after which it is filtered off, washed with boiling-hot water as long as any chloride of barium is extracted, and then placed in the water or air-bath to dry: the precipitate is now to be detached from the filter, upon a sheet of clean dry glazed paper; the filter is burned alone in the platinum crucible till the ashes contain no charcoal from the paper; the precipitate is then introduced, heated to redness, and weighed. One hundred and seventeen grains of the precipitate—corresponding with forty grains, or one equivalent of anhydrous sulphuric acid—equal eighty grains of anhydrous sulphate of copper, or one hundred and twenty-five grains of that salt in crystals.

The amount of the lime compound may be ascertained by weighing out one hundred grains, and dissolving them in a beaker-glass with hydrochloric acid, the clear solution filtered off from the residue, and a current of sulphide of hydrogen gas passed through the liquid, till the whole of the copper is thrown down in the form of a brownish-black precipitate. The sulphide of hydrogen—hydrosulphuric acid—is generated in an apparatus like the annexed—Fig. 29:

Fig. 29.



A is a bottle containing pieces of sulphide of iron, and a few ounces of water; through the cork two tubes pass, the funnelled one, B, reaches to the bottom, and the other, C, opens at a quarter of an inch below the cork, which should fit the bottle air-tight. The sulphide of hydrogen is generated by pouring, through the funnel tube, B, some strong sulphuric acid, which reacts on the sulphide of iron, giving rise to the gas, which passes off by the tube, C, bent at right angles, the longer limb passing through the cork of the bottle, *d*, which contains some distilled water, for the purpose of washing the gas. A second tube, *e*, bent at right angles, conveys the gas to the beaker-glass, *g*, containing the solution, from which the substance is to be precipitated.

The subjoined equation exhibits the decomposition of the sulphide of iron by the sulphuric acid:—

$$\underbrace{Fe\,S}_{\text{Sulphide of iron.}} + \underbrace{H\,O,\,S\,O_3}_{\text{Sulphuric acid.}} = \underbrace{Fe\,O,\,S\,O_3}_{\text{Sulphate of iron.}} + \underbrace{H\,S}_{\text{Sulphide of hydrogen.}}$$

When the whole of the copper has been precipitated as sulphide, and the menstruum evolves a strong odor of the precipitant, it is filtered off, edulcorated with water, and the washings added to the filtrate. Ammonia, in slight excess, is now poured into the solution, then oxalate of ammonia, and the beaker-glass placed on the sand-bath. When the oxalate of lime has subsided, it is collected, washed with water, dried as the preceding precipitates, and burned in a platinum crucible. The ignition should be gentle, and at a heat little above dull redness, so as not to expel carbonic acid from the carbonate of lime, which is formed by the action of the heat on the oxalate of lime, as is shown in the annexed decomposition:—

$$\underbrace{Ca\,O,\,C_2\,O_3}_{\text{Oxalate of lime.}} = \underbrace{Ca\,O,\,C\,O_2}_{\text{Carbonate of lime.}} + \underbrace{C\,O,\text{ expelled.}}_{\text{Carbonic oxide.}}$$

The weight of the carbonate of lime obtained is equal to the amount of that adulterant added to the verdigris. Verdigris generally contains about three per cent. of impurities, and sometimes the insoluble matter in it is six per cent.; in such a case, however, the article is of inferior quality.

Formerly, the manufacture of verdigris was one of the most lucrative in Belgium, and it was also carried on profitably in France; but in later times the production of this substance is not so much confined to those countries. France still produces considerable quantities of the article, and nearly the whole of the salt imported into this kingdom is from that country. Until the 19th of March, 1845, the duty on verdigris imported into this kingdom from France, was 1$\frac{1}{20}$d. per pound weight; it was then subjected to an *ad valorem* duty of ten per cent., which was repealed in 1853.

The following table shows the quantity of verdigris chargeable with duty, imported into the United Kingdom during the six years ending the 5th May, 1846:—

	1841.	1842.	1843.	1844.	1845.	1846.
Cwt.,	1,340 ..	1,702 ..	1,816 ..	1,218 ..	897 ..	454

Of which there were retained for home consumption, and chargeable with duty, in—

	1841.	1842.	1843.	1844.	1845.	1846.
Cwt.,..	888 ..	1,576 ..	1,575 ..	1,129 ..	791 ..	677

During the years 1845, 1846, and 1847, there were imported from France alone, in—

Year.	Quantity imported chargeable with duty.	Declared value.	Duty received for home consumption.
1845,....	100,679 lbs.	£6,640	£227
1846,....	49,180 "	3,102	110
1847,....	76,200 "	4,971	170

The quantities of verdigris which entered the port of London during the corresponding four months, terminating the 5th of May, were, in—

	1845.	1846.	1847.	1848.
Cwt.,....	256	123	216	2

And the quantities retained for home consumption, and chargeable with duty, during the corresponding months above-mentioned, were, in—

	1845.	1846.	1847.	1848.
Cwt.,....	176	136	19	76

In 1852, the last year of the existence of the ten per cent. *ad valorem* duty, the imports of verdigris were four hundred and sixty-seven, and the exports seventy-two hundredweight. In 1853, the duty, as already stated, was entirely repealed; still, the imports are small, as large quantities of verdigris are prepared in England with pyroligneous acid and cider refuse. The foreign salt sells at a shilling per pound, and the English variety, made from cider refuse, at ninepence, as it has a greenish color, and is in every respect inferior to the former.

ACETATE OF THE OXIDE OF ETHYLE.—*Acetic Ether.*—This compound is prepared by distilling ten parts of anhydrous acetate of soda with seven parts of sulphuric acid and eight of absolute alcohol. The fluid which passes over is mixed with carbonate of soda till neutralized, the supernatant layer of aqueous acetic ether drawn off and agitated repeatedly with dry chloride of calcium, until that salt is no longer moistened with it; the solution is then distilled to procure the pure ether. It is a colorless mobile liquid, having an agreeable refreshing odor, and a pleasant taste; it burns with a yellowish flame, producing acid vapors. Its spec. grav. is 0·89 at 60° Fahr.; it boils at 165°, and is converted into vapor of spec. grav. 3·0634.

The liquid is soluble in seven parts of water, and in alcohol and ether in all proportions. Its composition is appended:—

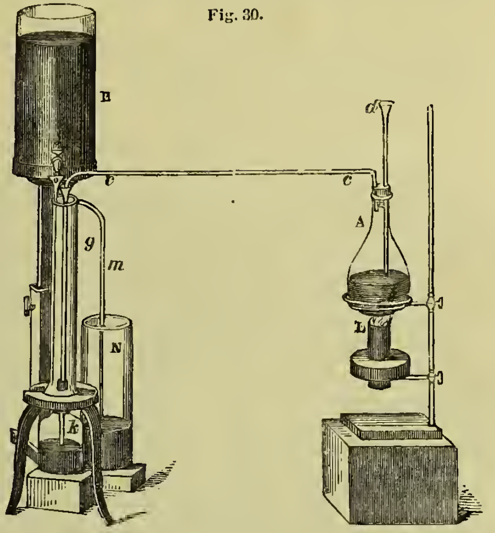
	Atomic weight.	Per centage weight.
8 Eqs. of carbon,...........	48	54·55
8 Eqs. of hydrogen,........	8	9·09
4 Eqs. of oxygen,...........	32	36·36
	—	——
1 Eq. acetic ether, ...	88	100·00

Formula:—$C_4\ H_5\ O,\ C_4\ H_3\ O_3$, or $C_8\ H_8\ O_4$.

Fig. 30 is a convenient form of apparatus for making acetic ether. A is a large flask, furnished with an air-tight cork, perforated with two holes, through one of which a safety or funnel tube, *d*, passes, and the other receives the tube, *c c*, bent at right angles as seen in the figure, through which the vapors pass to the condenser. The condenser, *g*, is a wide cylinder, having an aperture at the bottom, through which the bent end of the tube passes into a flask, *k*, placed beneath the cylinder to receive the distilled products. A cistern, E, supplies the cylinder, *g*, by the stopcock, *j*, with cold water, which is conducted to the bottom by the funnel pipe, *o*, and the partly-heated water passes off by the overflow pipe, *m*, into the vessel, N. Heat is applied to the flask by means of the spirit lamp, L.

Acetate of lead is a salt occasionally employed on the large scale, when making acetic ether; the proportions taken are, sixteen parts of dry acetate of lead to four and a half of absolute alcohol, and six parts of sulphuric acid, specific gravity 1·84. The sulphuric acid and alcohol are mixed in a vessel surrounded by ice, and the mixture, when cooled, is poured upon the finely-divided lead salt in the flask; the apparatus is adjusted, and a gentle heat applied at first, which is gradually increased towards the end of the distillation. The condenser is well cooled, and the receiver may be advantageously immersed in ice-cold water. The acetic ether obtained is rectified as before-mentioned.

Fig. 30.



When this ether is poured upon chloride of calcium, combination takes place, and a crystalline mass results, from which, by the addition of a small quantity of water, acetic ether again separates. By digestion in a solution of potassa, acetic ether suffers complete decomposition; acetic acid unites with the alkali, and ether passes off: the same effect is produced when the ether is distilled with lime. Hydrochloric, sulphuric, and nitric acids decompose it, the ether uniting with these acids and liberating acetic acid. Pure acetic ether does not react on blue litmus paper, nor should it be colored by sulphide of hydrogen. It dissolves resins, sulphur, phosphorus, *et cetera*, like ether.

This compound is used as a constituent of several of the pharmaceutical preparations employed in medicine. From its power of dissolving resins and essential oils, it may be advantageously applied in the preparation of varnishes. The vinegar sold contains a small quantity of acetic ether, with the view, no doubt, of improving its taste and odor.

ACETATES OF IRON.—There are two acetates of iron: the *protoacetate* and the *sesquiacetate.*

PROTOACETATE OF IRON may easily be prepared by dissolving sulphide of iron, or iron turnings, in acetic acid. In the former case, sulphide of hydrogen, and in the latter, gaseous hydrogen is evolved. This compound may likewise be obtained by decomposing a solution of the protosulphate of iron by acetate of baryta; but in this method there is formed a greater or less amount of sesquisalt, which can, however, be reduced to the state of protosalt by passing a stream of sulphide of hydrogen gas through the liquid. The protoacetate of iron crystallizes in prismatic crystals of a greenish color, which are very soluble in water, and readily pass into the state of basic acetate when exposed to the air. The composition of the dry salt is—

	Atomic weight.	Centesimal quantities.
1 Eq. of protoxide of iron, . . .	36	41·379
1 Eq. of acetic acid, ...	51	58·621
	87	100·000

Formula:—$FeO, C_4 H_3 O_3$.

For commercial purposes, this compound is manufactured as follows:—Into a large cast-iron boiler or pot, a quantity of iron turnings, hoops, or nails, are introduced, and acetic acid—the crude pyroligneous acid from the distillation of wood—is poured in upon them. The strength of the acid is generally of 7° Twaddle, or spec. grav. 1·035. A temperature of 150° Fahr. is maintained till the solution of protoacetate of iron is obtained, of a spec. grav. 1·09, or 18° T., at 60° Fahr. During the solution of the iron much tarry matter separates, which is skimmed off, and the solution frequently agitated, to free it, as much as possible, from the tar. As soon as the above strength is gained, the solution is allowed to cool, for a further quantity of impurities to separate. When clean turnings are operated upon, the process of solution is completed in five to seven days. The hydrogen that is eliminated during the solution of the iron prevents the oxidation of the iron salt, as is seen in the subjoined equation:—

$$Fe + \underbrace{HO, C_4 H_3 O_3}_{\text{Acetic acid.}} = \underbrace{FeO, C_4 H_3 O_3}_{\text{Protoacetate of iron.}} + H.$$

Were any sesquisalt formed, the hydrogen, by combining with part of its oxygen, would again reconvert it to a protosalt.

Some printers dissolve the iron without the aid of heat, but this method is slow and unsatisfactory, for the deposit of tarry bodies on the iron prevents the action of the acetic acid; besides, from the long exposure to the air, some sesquisalt of iron is generated. The usual produce from one hundred gallons of acetic acid, and a proportionate quantity of iron turnings, is sixty to seventy gallons of acetate of iron, spec. grav. 1·090, or 18° T., and when this solution is reduced by the addition of water to a spec. grav. 1·060, it produces with madder a deep black.

The mordant is likewise made by decomposing a solution of sulphate of iron by acetate of lime; the proportions employed are the following:—

400 lbs. of protosulphate of iron—copperas—dissolved in 100 gallons of hot water, and the solution decomposed by 75 gallons of acetate of lime liquor, spec. grav. 1·08.

On agitating the menstruum, the decomposition is rendered complete; the clear liquor, which is siphoned off after subsidence of the sulphate of lime, possesses a density of 1·110.

When the liquor is not immediately required for use, it is apt to become oxidized, and deposits a basic salt, to prevent which some metallic iron is left in contact with the solution—this will combine with the oxygen of the sesquioxide. Sometimes, when a large quantity of pyroligneous matters deposits in the solution, the iron is prevented from acting by the coating of those matters which fall upon it; in such instances, a quantity of fine iron wire may be suspended in the liquid, and thus the formation of the basic acetate is prevented.

In some of the continental factories, the protoacetate of iron is manufactured by decomposing the protocarbonate of iron with acetate of lead: carbonate of lead precipitates, and the blackish supernatant liquor is the protoacetate of iron in a very pure state. It is kept from oxidizing by immersing in it some bright iron filings. The lead-salt formed repays the cost of the manufacture of the acetate. This method is, however, as yet limited.

SESQUIACETATE—PERACETATE OF IRON.—This salt is made by dissolving pure hydrated sesquioxide of iron in acetic acid, or by mixing solutions of sesquisulphate of iron and acetate of baryta in an iron pot, and agitating the liquid. Sulphate of baryta precipitates, and the clear liquid contains the sesquiacetate. It is an uncrystallizable, dark, brownish-red liquor, which, on evaporation, yields a deliquescent gelatinous paste. Like the acetate of alumina, it deposits an insoluble basic salt when heated, and hence its utility in dyeing operations. *Basic* acetate of the sesquioxide of iron is an insoluble yellow powder, precipitating out of the protoacetate which has oxidized in the air, and even out of the neutral sesquiacetate when kept for some time, especially if an alkaline salt be present. When pure, the composition of the sesquiacetate of iron is—

	Atomic weight.	Per cent.
1 Eq. of sesquioxide of iron, ...	80	34·344
3 Eqs. of acetic acid, ...	133	65·656
1 Eq. sesquiacetate of iron, ...	213	100·000

Formula:—$Fe_2 O_3, 3 C_4 H_3 O_3$.

Sesquiacetate of iron is manufactured chiefly for the use of dyers, the salt being rarely employed by the calico-printer.

Where the dyer requires uniform grounds, he cannot as well employ the protosalts of iron, for when cotton is impregnated with such a solution as copperas or the protoacetate of iron, while drying it attracts oxygen from the air, and the sesquioxide of iron, or a basic salt, collects more in those parts not yet dry, and will, of course, produce darker spots in the dye-bath. It is, therefore, better to prepare an acetate of the sesquioxide of iron at once, either by pouring acetic acid repeatedly over iron turnings for several weeks, in vessels exposed freely to the air, or, still better, by double decomposition with acetate of lead or acetate of lime. For this purpose, dissolve one pound iron-alum in half a gallon of water, add one pound acetate of lead, stir the liquor well, let it settle, and decant or filter. The solution made from iron-alum will not keep long, as it gradually deposits an insoluble basic salt from the presence of sulphate of potassa, while that made from sesquisulphate of iron will retain its properties for a great length of time; on the other hand, iron-alum is more convenient in use, from its containing known quantities of sesquioxide, and the difficulty above-mentioned may be obviated by preparing only the quantity required for immediate use.

The sesquiacetate of iron may also be made from sesquisulphate of iron and acetate of lead. As the sesquisulphate of iron is not so uniform in composition as the iron-alum, it may be well to ascertain how much oxide of iron and sulphuric acid it contains, in order to know what quantity of acetate of lead to employ in its decomposition. For this purpose, weigh out one hundred grains, which is about half an equivalent of dry and pure sesquisulphate; dissolve in water, and filter; add two hundred and eighty-five grains crystallized acetate of lead—half of three equivalents—dissolved in water, filter and weigh the precipitate, which is sulphate of lead: every seventy-six grains of this sulphate of lead require ninety-five or more—safely, ninety—grains of acetate of lead to insure sufficient decomposition. Calling grains, pounds, the operation may then be conducted on a large scale. The excess of acetate of lead in the acetate of iron mordant, may be ascertained by diluting a little of the clear liquor with water, and adding a few drops of sulphuric acid; if it becomes cloudy, there is an excess of acetate of lead, which may prove injurious to colors, but this is easily obviated by adding a little more sesquisulphate of iron, until the clear liquor is no longer affected by sulphuric acid. For the ordinary operations of the dyer, it may not be necessary to decompose all the sesquisulphate of iron; but for printing, and particularly for full russets, the whole salt should be sesquiacetate of iron, otherwise some of the sulphate would disappear in washing the goods, while they may be fully charged with basic acetate of iron, which cannot be removed by water.

The acetates of iron are employed in woollen dyeing, to produce blue with ferrocyanide of potassium—yellow prussiate; in cotton dyeing and printing, and in silk dyeing, for blacks, russets, *et cetera;* the protoacetate with madder, for violet; the same, together with red liquor, for brown; in dyeing hats and furs black; for blackening leather, wood, *et cetera.* Some prefer the protoacetate, because, by the oxidation of the iron subsequent to dyeing, the colors are more resistent; but greater uniformity of the ground is insured by the use of sesquiacetate.

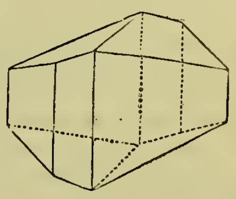
The sesquiacetate of iron, containing protoacetate, may also be conveniently made by pouring pyroligneous acid on iron turnings in a series of vessels placed obliquely one above the other—as will be more particularly described under acetate of lead—suffering the acid to remain the same length of time in contact with the metal, and repeating the operation twice, or until the acid is saturated.

Pyroligneous acid—crude wood vinegar—is now almost universally employed for the manufacture of the protoacetate and sesquiacetate of iron.

ACETATE OF LEAD.—*Sugar of Lead; Salt of Saturn,* of the old chemists.—Oxide of lead unites with acetic acid in various proportions, the most important of those combinations being the neutral acetate, known in commerce under the above names. It is used to a great extent in the calico-printing business, and likewise in dyeing, for the preparation of other compounds employed in those trades, and occasionally as a medicinal agent, and in pharmaceutical preparations.

It may be prepared by digesting pure oxide of lead in dilute acetic acid, or by exposing thin sheets of lead in a confined chamber to the action of the vapor of acetic acid; they become corroded, and there is formed a mixture of carbonate and acetate of lead on the surface of the sheets, which is scraped off, and dissolved in a slight excess of acetic acid. On evaporating this solution, the acetate of lead crystallizes in acicular masses, if the hot solution be set aside to cool rapidly; but if the evaporation be conducted slowly, the crystals are truncated and flattened quadrangular and hexahedral prisms—Fig. 31—derived from a right rhombic prism. The crystals are permanent in the air, but are apt to effloresce and become anhydrous if the temperature ranges between 70° and 100° Fahr. Anhydrous acetate of lead is soluble in boiling absolute alcohol, and is deposited again in hexagonal plates on the slow cooling of the spiritous solution. Acetate of lead has a sweet astringent taste, is soluble in less than three and a half times its weight of boiling water, and in nearly the same quantity of cold water. PAYEN states, that a hundred parts of water at 60° Fahr., dissolve fifty-nine parts of the crystallized acetate of lead. The crystallized salt is fusible in its water of crystallization at 130°, boils at 212°, and after elimination of the water solidifies into a lamellar mass.

Fig. 31



On raising the temperature higher, the substance fuses, and evolves all the compounds usually obtained in the destructive distillation of the acetates of the heavy metals, leaving a residue of highly pyrophoric metallic lead, in a very minute state of division, with some charcoal.

A slight decomposition occurs when the neutral salt is exposed to an atmosphere of carbonic acid—carbonate of lead being formed; the portion of acetic acid thus liberated protects the remainder from further change.

The anhydrous acetate is composed of—

	Atomic weight.	Per centage weight.
1 Eq. of oxide of lead,	112	68·71
1 Eq. of acetic acid,	51	31·29
1 Eq. of acetate of lead,	163	100·00

and the composition of the crystallized salt is—

1 Eq. of oxide of lead,	112	58·95
1 Eq. of acetic acid,	51	26·84
3 Eqs. of water,	27	14·21
1 Eq. of crystallized acetate of lead,	190	100·00

Formula:—$PbO, C_4 H_3 O_3 + 3 HO$.

BROWN ACETATE OF LEAD.—The distilled pyroligneous acid is saturated with litharge in a tub, and the muddy solution ladled out into a large tun to settle; the solid matter readily subsides, and the clear solution is transferred into a pan of malleable-iron, but which may be made of cast-iron, and six feet long by four feet broad. The solution is brought to the boiling point in this pan, then allowed to settle; it is next transferred into a large hemispherical pan, capable of holding about three hundred or four hundred gallons, where it is evaporated down to about crystallizing strength. When the solution has become dense enough to crystallize, about three times its bulk of water is run in upon it whilst boiling, the solution being constantly stirred. By this treatment a considerable quantity of impurities is disengaged, which may be skimmed off as fast as they rise to the surface; after they are removed, the evaporation goes on as before. If the solution be still too much colored, another dose of water must be given. A little practice soon enables the operator to know when the evaporation should be checked. The ordinary method is, to rinse a ladle—which is used to skim off tar from the solution —through the liquid, and observe how many drops fall from it before the solution takes a stringy appearance; if only ten or twelve fall, then it is sufficiently strong. The liquid is now ladled out into malleable-iron pans to crystallize; the pans are five feet long by three feet broad, and about six inches deep, the sides being bevelled or sloping outwards from the bottom. After the crystals have become sufficiently firm, the sugar of lead is taken out, by inverting the pan on a cloth. The pots used in the above process are heated only at the bottom.—*A. P. Halliday.*

White Acetate of Lead.—This is prepared by dissolving litharge in acetic acid. The acetic acid is introduced into a vessel, the litharge added by degrees, and the menstruum kept in brisk commotion after each addition, until the solution only slightly reddens litmus paper; a quantity of water, equal to about one-half of the acid employed, is then run into the lead solution; heat is applied, and the mixture slowly evaporated for about twelve hours, or until it has acquired a density of about 1·500. During evaporation, any impurities which rise to the surface are skimmed off, and when the solution has acquired its proper gravity, it is drawn into the crystallizing pans. When the crystals have become sufficiently hard to allow of their being taken *en masse* from the crystallizers, they are drained and placed on wooden racks in the drying-house, and, when dry, cleaned and broken up into fragments for the market.

The mother liquor, which contains neutral and basic acetates of lead and other metallic salts, may either be treated with vinegar, evaporated, recrystallized, and the residue employed as washings in subsequent operations; or it may be decomposed by carbonate of soda or lime, and used as carbonate of lead; or dissolved in acetic acid, and the supernatant acetate of soda or lime recovered.

Vessels used in this manufacture are, in most cases, of lead. In Wales, the mixing pans are of lead, three quarters of an inch thick, seven feet long by four and a half feet wide, and one foot deep. These pans are set on iron plates over arches, and the fireplaces are outside the building, in order that the acetate may not be darkened by the sulphurous vapors from the coal. The crystallizing pans are of wood, lined with thin copper, and are about four feet long by two feet wide, and from six to eight inches deep, sloping inwards at the edges. At Pitchcombe, the mixing and crystallizing vessels are both of copper, having a strip of lead soldered down the sides and across the bottom of the vessel, to render the metals more electro-negative, whereby the acetic acid is prevented acting on the copper. Very great care is requisite in the drying of the sugar of lead; the temperature of the desiccating-house should not exceed 90° Fahr. In Wales, the heated air of a stove, placed outside the drying-house, is conveyed through pipes passing round the interior; at other places, steam heat is the agent for this purpose, which is much to be preferred on account of its being more easily regulated.

That the manufacturer may the better judge of the success of his operations from the amount of the product obtained, the following will serve as a precedent:—One hundred and twelve pounds of good Newcastle litharge should produce a hundred and eighty-seven pounds of sugar of lead, when treated with a hundred and twenty-seven pounds of acetic acid of spec. grav. 1·057, but not more than a hundred and eighty pounds are obtained in practice. The quantity produced, given in Ure's Dictionary of Arts and Manufactures, and in other works, is evidently a misprint, being almost three times the weight of the litharge employed. A manufacturer of sugar of lead would indeed be fortunate who could obtain such a return. In a factory in Wales, a ton of Welsh litharge produces, with the acid obtained from one ton of acetate of lime, from twenty-eight to thirty hundred weight of sugar of lead; and in another manufactory, one ton of best Newcastle litharge, with the acid from one ton and a half of acetate of lime, produces thirty-three hundred weight of the lead salt.

The following process with metallic lead, recommended first by Berard, is easily executed, and is said by Runge to yield a good product with great economy. Granulated lead, the tailings in the white lead manufacture, *et cetera*, are put in several vessels—say eight—one above the other, upon steps, so that the liquid may be run from one to the other. The upper one is filled with acetic acid, and after half an hour let off into the second, after another half hour into the third, and so on to the last or eighth vessel. The acid causes the lead to absorb oxygen rapidly from the air, evolving heat, so that, when the acid runs off from the lowest, it is thrown on the uppermost vessel a second time, carries off the acetate of lead formed, and after passing through the whole series, the solution is so strong that it may be evaporated at once to crystallize. There are two points of importance in this manufacture. Whatever method may be pursued, a strong acid is to be employed, that less of it may be lost in concentrating the liquid, and, likewise, to economize time, and retain an acid reaction in the liquid, by which the formation of a basic salt is prevented.

It may not be amiss to call attention here to a process, patented about ten years since, for preparing acetate of lead and other acetates. It consists in employing the acid in the state of vapor, to act upon the bases, instead of using it in the liquid form. A vessel is provided of adequate capacity for the quantity of acetate required, and constructed of such material as will not be readily destroyed by the acid. The top of this vessel is closed hermetically by a cover, fastened down by any convenient means, and in the lower part of the vessel is placed either a minutely-perforated false bottom, or a coiled tube of several convolutions, minutely perforated, to permit vapor to permeate freely. To prevent the loss of acid, there is also placed, at different degrees of elevation, several perforated diaphragms, similar to the false bottom just mentioned, on each of which is spread a layer of litharge, after which the cover of the vessel is to be accurately closed. By means of an ordinary distillatory apparatus, liquid acetic acid—strong or weak, pure or impure—is converted into vapor, which is then conducted by means of a pipe into the convoluted and perforated one before mentioned, or between the real bottom of the vessel and the perforated false bottom; hence the vapor, passing through the numerous perforations of the false bottom and diaphragms, diffuses itself throughout every part of the vessel, its acid entering into combination with the base employed, and forming the acetate, which falls to the bottom of the vessel, and in its descent meets with the ascending streams of vapor, the acid of which renders it perfectly neutral; meanwhile the more aqueous parts of the vapor become liberated, and maintaining their temperature ascend, and in their passage through the successive layers of the base are deprived of their remaining acid. The vapor, thus reduced to simple steam, is allowed to escape through one or more pipes at the top of the vessel, and as this still maintains a boiling temperature, it is conducted through a worm to evaporate the acetate or mother liquor. Distillation of the acid is continued until the acetate in the vessel has acquired the proper degree of concentration for crystallization, which is easily ascertained by examining a small quantity drawn off by a tap at the bottom of the vessel, through which the whole contents are discharged when the operation is completed. As the work draws to its close, nearly all the base having combined with the acid, the vapor issues out of the vessel charged with a certain portion of acid; and that no loss may be sustained by its escape into the atmosphere, it is conducted into another vessel prepared like the first-mentioned, but charged superabundantly with the base, to take up every particle of the acid issuing from the first vessel, until the contents of the latter are converted into acetate of lead. As the temperature of the solution of the acetate can never exceed that of the vapor, the crystalline product is of fine quality.

ACETATE OF LIME.—This salt is formed when pure carbonate of lime is dissolved in acetic acid. The action is as follows:—

$$\underbrace{CaO,\,CO_2}_{\text{Carbonate of lime.}} + \underbrace{C_4H_3O_3,\,HO}_{\text{Hydrated acetic acid.}} = \underbrace{CaO,\,C_4H_3O_3}_{\text{Acetate of lime.}} +$$

$$HO + CO_2.$$

According to PELOUZE, the carbonate of lime does not dissolve in the monohydrated acid. The pure salt crystallizes in silky, acicular prisms, of a bitterish saline taste, which effloresce when heated to 212°. It is soluble in water and alcohol. The dry salt has the property of being phosphorescent in the dark, when triturated at 226° Fahr. Its composition is—

	Atomic weight.	Per centage weight.
1 Eq. of lime,	28	35·4
1 Eq. of acetic acid,	51	64·6
1 Eq. of acetate of lime,	79	100·0

When speaking of the preparation of pure acetic acid from wood acid—page 28—a curtailed account of the production of this compound was given, as likewise for the acetate of soda. A modification of the method there mentioned, for the production of a purer article for the market, will be here considered. The following is the mode of working in large factories:—The crude acid liquor from the distillation of wood, after separating the pyroxylic spirit, is either distilled or run off into other convenient vessels, according as the *grey* or *brown* acetate is to be procured. In either case, the subsequent procedure is the same. Five hundred or one thousand gallons of the liquid are run off into wooden or iron vessels, of suitable capacity, and powdered chalk or slacked lime added, till a slight excess remains undissolved, and the whole agitated briskly for some time, in order to insure complete combination. The menstruum is then allowed to rest at a temperature of 150°, till the excess of lime and tarry compounds subsides, when the clear supernatant liquid is siphoned off into the evaporating pans, which, in most factories, are wooden vessels lined with lead, and heated by coils of iron pipes placed within them, through which steam passes; in some factories they are shallow, and made of sheet-iron, and placed together directly over the fire. The solution of the lime salt is kept simmering, and briskly agitated during the evaporation, and the scum of tarry impurities that agglomerates at the surface must be skimmed off. Acetate of lime, as soon as it begins to form, is separated from the liquor by the skimmers, and thrown into wicker baskets suspended over the pans, so that the solution draining from the salt may not be allowed to cool. The subjoined practical results were obtained by the use of three sheet-iron pans of about eighteen inches in depth, each capable of containing four hundred and fifty gallons of the solution.

	Number of gallons of liquor evaporated.	Producing of dry acetate of lime,
In the first six days, of twenty-four hours each,	7,020	78 cwt.
In the second six days, of twenty-four hours each,	8,060	92 "
In the third week of six days, of twenty-four hours each,	7,000	78 "

Two of the pans contained *brown* acetate of lime liquor.

The yield of acetate here mentioned is of course dependent upon the variety of wood submitted to distillation, as also upon its state of dryness and the proper regulation of temperature. That part of the process which demands the greatest attention is the *drying*, as on the proper execution of it the success of the operation in a great measure depends. Several methods are in use for drying the lime salt, some of which cannot prove efficient to the manufacturer. In some factories, the salt is dried by spreading it in thick layers on the top of the brickwork surrounding the carbonizing retorts and steam-boilers; but in large works, where ten, twelve, or fifteen thousand gallons of liquor are evaporated weekly, the products could not be dried in this way. In well-regulated factories, it is customary to have a drying-house apart for the purpose, and where lime is burned on the premises the heat from the kilns is advantageously applied to drying the lime salt, by conducting it through flues in the floor of the drying-house. As a rule, there should be a drying-house attached to every factory, for exsiccating the acetates, as the want of it may entail the loss of the whole product of the distillation of the wood, so far as the acetic acid is concerned. The following description of a drying-furnace is taken from an article on wood vinegar, and the manufacture of some of the acetates, in the Pharmaceutical Journal:—

The drying apparatus is a simple wind furnace, seven or eight feet long, and four and a half feet broad, built of brick. At six inches above the ground is the ash-pit, eight inches broad and twelve inches high, which is covered with a grate of bricks. The fireplace is twenty inches high, and ten inches broad, at the grate; over it is an arch of bricks, so that the fire cannot play on, and heat very highly, the iron drying-plate lying on the side of the hearth. The space below the drying-plate is separated from the hearth by a partition of bricks, three or four inches high; twelve inches above the outlet of the hearth is a layer of iron bars, one and a half to two inches from each other, and upon these is deposited the drying-plate. This consists of cast-iron, a quarter of an inch thick, and is formed according to the size of the furnace. Round the plate the furnace is built up to the height of ten inches on the side of the front wall, leaving room for doors, which may be calculated at two and a half feet. These doors are two, one above the other, through which the whole interior of the furnace can be inspected. They are formed of plate-iron, and have in their middle a sliding door, to admit of the exit of the vapor of the acetate of lime, and of some ventilation. A wall built at the end of the plate, or a clay partition, separates the whole of the drying-plate from the chimney. In the walls of the furnace, iron bars are fixed, and upon these a second drying-plate covers the drying space. This plate, as it does not come in contact with the fire, may consist of good iron, or of clay. Above this drying space another is formed by means of the chimney. The heat passes as well under as above the drying space, thence into the chimney, which is situated at the side of the furnace, and can be shut by a valve. The prevailing temperature in the drying-room is 167° to 235° Fahr. Turf forms the best material for fuel, as it does not burn rapidly, and produces a steady and equal temperature.

When the furnace is equally heated to the proper temperature, the fire is slackened. If wood be employed for fuel, the sliding door should be opened at the commencement, in order to allow the moisture to escape. The salt is transferred from the baskets over the evaporating pans to the drying-plate, and spread out to the depth of two inches, and after the first portion has become somewhat dry, the depth is increased to four or five inches; the heat, as already mentioned, is kept up for twenty-four hours, during which the salt is repeatedly turned. Subsequently, when the mass appears to be becoming dry, the temperature is raised to 257° Fahr., in order to expel every trace of water; in doing so, however, care must be taken that it is gradually applied, and that no fume is expelled from the acetate of lime, for then decomposition of the salt would be taking place; neither should any spark of fire be suffered to come in contact with the dried salt, since it possesses the characteristic property of igniting and burning like sugar of lead. During the drying by this means, the tarry and oleaginous matters with which the acetate is impregnated are decomposed, a black charcoal remaining, which appears in streaks through the dry mass. On dissolving the desiccated acetate of lime in three parts of hot water, and filtering through coarse animal charcoal or gravel, the charcoal and decomposed carbonaceous matters of the salt are retained; and the solution, upon evaporation and subsequent torrefaction of the residuary matter, affords a very pure and nearly colorless product The average yield of this salt from one ton of wood, is one hundred and forty pounds.

ACETATE OF MANGANESE.—This compound is prepared by dissolving pure carbonate of manganese in acetic acid, evaporating the solution, and crystallizing. The crystals are of the rhombic prism, and occasionally in plates of an amethystine color; they are permanent in the air, soluble in alcohol, and in about three and a half times their weight of cold water. The composition of the dry salt is—

	Atomic weight.	Per centage composition.
1 Eq. of protoxide of manganese,	28	41·38
1 Eq. of acetic acid,	51	58·62
	79	100·00

Formula:—$Mn\,O,\ C_4\,H_3\,O_3$.

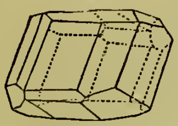
On the large scale, this salt is manufactured by precipitating a solution of the sulphate of manganese by one of acetate of lime, and agitating the liquor to decompose the whole of the sulphate of manganese.

It happens that a portion of the manganese salt is not acted upon by the acetate of lime, and to effect the complete decomposition a concentrated solution of acetate of lead is employed towards the end. The mixed precipitate of sulphate of lime and lead is filtered off, and the filtrate evaporated and crystallized, or used directly, if deemed necessary. The best acetate of manganese is made by adding to four parts of sulphate of manganese in three parts of water, seven parts of crystallized acetate of lead dissolved in three parts of water, agitating the solution, and drawing off the clear liquor for use.

Acetate of manganese is used in dyeing and calico-printing, to give a brown color to fabrics. Its principle of action depends upon the oxidation of the protoxide. The cloth is well steeped in a concentrated solution of the acetate of manganese, and printed; it is then passed through a bath of hypochlorite of lime—bleaching powder—which converts the protoxide of manganese into a higher oxide, producing a brown color on that which, previous to the immersion in the bleaching or chloride of lime solution, was colorless.

ACETATE OF SODA.—This salt is formed by dissolving carbonate of soda in acetic acid, evaporating the solution, and setting the liquor aside to crystallize. The crystals are oblique rhombic prisms—Fig. 32—soluble in three parts of cold, in a less quantity of boiling water, and in five of alcohol.

Fig.32.



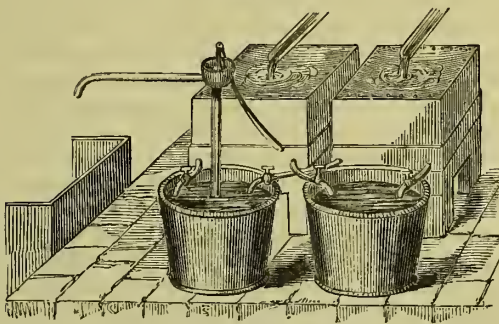
The composition of the dry salt is appended:—

	Atomic weight.	Per centage weight.
1 Eq. of soda,	31	37·8
1 Eq. of acetic acid,	51	62·2
1 Eq. of acetate of soda,	82	100·0

Formula:—$NaO, C_4 H_3 O_3$.

On the large scale, the manufacture is carried out in the following way:—A filtered solution of the common acetate of lime is precipitated by one of sulphate of soda, at 98° or 100° Fahr., till the whole of the lime is thrown down as sulphate. The strength of the solution of the lime-salt is 1·116, and of the soda solution 1·250; or the sulphate of soda may be added in powder, and the whole well agitated until no further precipitation of sulphate of lime takes place, using the precaution, however, of adding the sulphate of soda sparingly, so as to prevent its excess. The mixture, after thorough agitation, is drawn off into a deep vessel and allowed to repose, and when the precipitated sulphate of lime has completely settled, the clear liquor is siphoned off and conducted to the evaporating pans for crystallization, the lime-salt remaining being washed with successive portions of water, till the whole of the acetate of soda is separated. The first washings may be added to the strong solutions in the evaporating pans, and the others retained for dissolving fresh portions of acetate of lime for subsequent decomposition. Occasionally, the solution from the decomposing vessel is filtered, and the precipitate washed in the following manner:—One or two backs are provided, according to the size of the factory; these are placed over two cisterns, each cistern being connected with both the backs by pipes, branching from the latter to both cisterns; by means of a stopcock in those connecting pipes, the communication with either back may be cut off at will when required, as seen in Fig. 33. The backs are either square or circular, having false bottoms, in which are filters of stout twilled flannel. The charge from the decomposing pan is run on to one of the backs and filtered, till the whole of the strong liquor has passed into one of the cisterns; the connection with this cistern is then cut off, and when the washing of the residue commences, the pipe communicating with the other cistern is open, which conducts the washings into it. A fresh charge may be introduced into the second back, and the pipe reaching to the cistern holding the strong liquor opened, and thus the strong liquor is always obtained by itself ready for evaporation. Another advantage is, that while the residue in one back is in the course of being washed, the other may be filtering off strong liquor. The washing is continued till the percolations are nearly tasteless, and the residuary sulphate of lime dug out of the filters with wooden spades—iron spades cannot be used, as they are apt to cut the filters. Dilute solutions from the washing may be employed to dissolve fresh quantities of the acetate of lime for decomposition, by means of the soda-salt. The acetate of soda liquor is then pumped from the cisterns into the evaporating pans, which should be so constructed as to offer as much heated surface as possible, so that one man can keep their contents in brisk agitation. As the evaporation draws to a termination, much care and skill are required in keeping the liquefied salt well stirred, so as to have every part equally under the influence of the heat, and to prevent decomposition of the whole mass. The temperature should never rise higher than 500° Fahr., and in drying the acetate of soda, 450° to 470° is the temperature that should be applied. White fumes passing off from the fused mass are indicative of the decomposition of the salt, and if the fire be not checked immediately, nothing will be left but carbonate of soda and charcoal. If the purified acetate of lime be employed, the acetate of soda, obtained by dissolving the above product in water, evaporating and crystallizing, will be quite pure. For this purpose, the fused salt is dissolved in twice its weight of water, the solution filtered through filter-bags, and the liquor evaporated till it acquires a spec. grav. of 1·50, when it is drawn off to the crystallizing pans. These may be of boards lined with four-pound lead, four feet long, two feet wide, and nine inches deep. The concentrated solution of the salt is left in the pans for two, three, or four days, according to the temperature of the room, till a crop of crystals are produced; the crystals are separated and deposited in baskets, where they are allowed to drain, and the mother liquor remaining is returned to the evaporating pan, or it is employed to dissolve fresh quantities of the crude salt. The crystals are washed with cold water, to separate any adhering mother liquor, and placed on shelves to dry, when they are ready to be packed. The washings may be added to the mother liquor, and used as above.

Fig. 33.



The Pharmaceutical Journal gives the following mode for the purification of this salt:—The acetate of soda is dissolved in a large cylindrical lead vessel, heated by shooting steam into it. When the solution is completed, it may be run through a flannel filter into the top of a course of steamers, furnished with coils of three-quarter inch lead pipe. These vessels are made of four-pound sheet-lead, cased in boards; the best size is about twenty-four feet long, four feet wide, and nine inches deep. The pipe should be coiled from one end of the pan to the other, and should go up and down two or three times. Too much pipe cannot be used, as the rapidity of the evaporation depends upon the quantity employed. As the evaporation proceeds, the liquor ought to be siphoned from the top to the second, and afterwards to the third steamer, and thus room made for more bulky weak liquor from the dissolving lead: when a pellicle appears on its surface, it should be siphoned off into the crystallizers, and allowed to rest for two or three days, when beautiful crystals in oblique rhombic prisms are obtained. If very large crystals are required, the coolers are immersed in sawdust, or some other non-conducting material, and a longer time is allowed for them to form. In general cases, the amount of acetate of soda obtained from one ton of the lime-salt, ranges from twenty to twenty-two hundred-weight, but frequently a less quantity results. The impurities present in acetate of soda, are sulphate of soda and acetate of lime; the presence of the latter is caused by the imperfect decomposition of the acetate of lime by sulphate of soda, and of the former by a too abundant use of that salt in decomposing the acetate of lime. The sulphate of soda is separated by skimming off the crystals of this salt, which form before those of the acetate of soda; but the acetate of lime cannot afterwards be got rid of, and is injurious in *running the crystals*, as the workmen term it; that is, it prevents crystallization. The most economical method for manufacturing the acetate of soda, would be to neutralize the crude acid from the distillation of wood with sulphide of sodium; but the sulphide of hydrogen, given off in such enormous volumes, is a paramount objection to this method. In other factories, instead of evaporating the acetate of soda to dryness, and subsequently torrefying the dry mass, the purification is effected by repeated crystallizations and filtrations of the solution through animal charcoal, previously washed with hydrochloric acid.

The solutions recommended by MITSCHERLICH for this purpose, should have a density of 1·116 for the acetate of lime, and 1·24 for the sulphate of soda; when they are stronger, the impurities do not so readily subside.

ACETATE OF THE PROTOXIDE OF TIN.—This salt is also employed in calico-printing, to give light spirit colors to cloth. The process of manufacture is nearly the same as for the preceding. The proportions taken are, one hundred and three parts of crystallized protochloride of tin, dissolved in water, and one hundred and ninety parts of crystallized acetate of lead. It may likewise be prepared by dissolving protoxide of tin, or metallic tin, in acetic acid. In technical operations, the first method is usually followed. On evaporating the filtered solution to a syrupy consistence, and adding alcohol, the salt crystallizes in colorless transparent needles, which have a great tendency to oxidize, if at all exposed to the air.

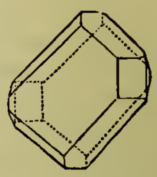
Another recipe is to dissolve thirty pounds of acetate of lead in forty gallons of boiling water, and add 18¾ pounds of crystals of the tin salt; the mixture is well stirred, allowed to settle, and the liquor filtered or siphoned off for use into casks or vessels, protected as much as possible from contact with the air. Some makers prefer to prepare the salt when immediately wanted for use.

ACETATE OF ZINC.—This salt may be prepared by dissolving metallic zinc, or oxide of zinc, in acetic acid, or by the decomposition of its sulphate by acetates of lime or lead, similar to the acetate of manganese—the decompositions, in these instances, being represented in the annexed equations:—

$$\mathrm{Zn + C_4\,H_3\,O_3,\,H\,O = Zn\,O,\,C_4\,H_3\,O_3 + H.}$$
$$\mathrm{Zn\,O + C_4\,H_3\,O_3,\,H\,O = Zn\,O,\,C_4\,H_3\,O_3 + HO.}$$
$$\mathrm{Zn\,O,\,S\,O_3 + Pb\,O,\,C_4\,H_3\,O_3 = Zn\,O,\,C_4\,H_3\,O_3 + Pb\,O,\,S\,O_3.}$$

The acetate is obtained, in the first two instances, simply by evaporation, and in the latter, after agitating the mixture, filtering and evaporating the menstruum, the salt crystallizes in flexible, opalescent, six-sided tables—Fig. 35—which effloresce slightly in the air. The composition of the dry salt is—

Fig. 35.



	Atomic weight.	Per centage weight.
1 Eq. of oxide of zinc, ...	40·5	44·27
1 Eq. of acetic acid, ...	51·0	55·73
1 Eq. of acetate of zinc, ...	91·5	100·00

Formula:—$\mathrm{Zn\,O,\,C_4\,H_3\,O_3}$.

According to SCHINDLER, the crystals contain three atoms of water when deposited from cold solutions, and only one atom when they are formed from concentrated hot ones. Technically, the best recipe is to dissolve four parts of the sulphate of zinc, and seven and a half parts of acetate of lead, each in three parts of hot water, mixing the solutions, agitating, and, after the sulphate of lead has deposited, drawing the clear liquid off to crystallize.

ALCOHOL.—*Alcool*, French; *Alkohol* or *Weingeist*, German; *Spiritus Vini Alcoholisat.*, Latin.—A preparation of antimony used to be designated by this name—the oriental females still use it for painting their eyebrows. The appellation was afterwards given to other fine powders, and to highly-rectified spirits.

There is no evidence of the ancients being acquainted with alcohol or ardent spirits; in fact, there is every reason to believe the contrary, and that distillation was quite unknown to them. This fact is more apparent from the method followed by DIOSCORIDES to obtain quicksilver from cinnabar—sulphide of mercury: he mixed the cinnabar with iron filings, put the mixture into a pot, to the top of which a cover of stoneware was luted; heat was applied, and when the process was terminated, the mercury was found adhering to the side of the cover. The children of the nineteenth century might well laugh at the docimastic notions of the old philosopher. DIOSCORIDES, however, was not without penetration and judgment, but he was unacquainted with the method of adapting a receiver to his pot, otherwise he never would have proceeded as above recounted. Another strong corroboration of the fact, that alcohol was unknown in former times is, that neither the poets, historians, naturalists, nor medical men, make the slightest allusion to ardent spirits—a circumstance which would not have happened had these liquids been applied to even a hundredth part of the uses made of them by the moderns.

In the strict chemical sense, the term *alcohol* is employed as a generic word for a class of bodies belonging to the same type, or framed upon the same principle. Just as *salt*, originally applied to chloride of sodium, or the condiment with which we season our food, is now extended to a class of bodies often destitute of savor; as *metal* designates several substances which do not possess either the malleability, the specific gravity, or the power of resisting heat, which characterized those from which the term was borrowed; or as *acid* appertains to many compounds having neither a sour taste nor any caustic properties; so *alcohol* indicates a class, some members of which, far from being volatile, are not even liquid, and, instead of igniting easily, require a pretty elevated temperature for kindling. The following are three properties by which the genus alcohol may be recognized:—

1. When subjected to the action of oxidizing bodies, it loses two atoms of hydrogen, sometimes replaced by two of oxygen, when it is converted into an acid, and in other cases eliminates the same without acquiring oxygen in its stead, when it produces an aldehyde.

2. Under the influence of substances having a strong affinity for water, such as sulphuric acid, chloride of zinc, and phosphoric acid, it has a strong tendency to lose two equivalents of water, and to be transformed into carbide of hydrogen, or else to split into water and ether.

3. Exposed to the action of chlorine, aldehydes are formed from it, owing to the abstraction of two atoms of hydrogen.

In the case of the alcohol produced from vinous fermentation, which one may call wine-alcohol, there is a body consisting of the oxide of a carbide of hydrogen, having the proportion of four equivalents of carbon to five of hydrogen, and united to an atom of water.

This compound may be converted into acetic acid by the abstraction of two equivalents of hydrogen, and the addition of two of oxygen, through the agency of potassa, and also by a variety of other bodies.

The effect of the decomposition would be as under:

$$\begin{array}{lr}
\text{Alcohol, } \dots\dots\dots\dots\dots\dots & C_4\,H_6\,O_2 \\
\quad\text{Minus, } \dots\dots\dots\dots\dots\dots & H_2 \\
\hline
\quad\text{Equal, } \dots\dots\dots\dots\dots\dots & C_4\,H_4\,O_2 \\
\quad\text{Plus, } \dots\dots\dots\dots\dots\dots & O_2 \\
\hline
\text{Acetic acid, } \dots\dots\dots\dots\dots\dots & C_4\,H_4\,O_4
\end{array}$$

and which, by the continuation of the action of the potassa, is broken up into—

$$\left.\begin{array}{ll}
\text{Carbonic acid, } \dots\dots\dots\dots & C_2\quad O_4 \\
\text{And light carbide of hydrogen, } & C_2\,H_4
\end{array}\right\} = \underbrace{C_4\,H_4\,O_4}_{\text{Acetic acid.}}$$

According to DUMAS, this decomposition is occasioned by the affinity of hydrate of potassa for carbonic acid, inducing, in the first instance, the resolution of the alcohol into that compound through the decomposition of the water of the alkali; hydrogen is evolved, whilst its oxygen carries off the hydrogen of the alcohol, thus—

$$\underbrace{2\,(C_4\,H_6\,O_2)}_{\text{Alcohol.}} + \underbrace{16\,(K\,O,\,H\,O)}_{\text{Potassa.}} = \underbrace{(K\,O,\,C_4\,H_3\,O_3)}_{\text{Acetate of potassa.}} + \underbrace{4\,(K\,O,\,C\,O_2)}_{\text{Carbonate of potassa.}} + \underbrace{11\,K\,O}_{\text{Potassa.}} + \underbrace{9\,H\,O}_{\text{Water.}} + \underbrace{16\,H.}_{\text{Evolved.}}$$

The Editor finds, that when alcohol and potassa are left at rest in a stoppled bottle for some weeks, the menstruum acquires a pinkish color; and when this mixture is distilled, acetate of potassa is found in the residue. Is the change owing to the decomposition of the water, as stated by DUMAS, or to the absorption of oxygen from the air?

$$2\,(C_4\,H_6\,O_2) + 5\,K\,O + 7\,O = K\,O,\,C_4\,H_3\,O_3 + 4\,(K\,O,\,C\,O_2) + 9\,H.$$

Other carbides of hydrogen, known or supposed to exist, give rise to similar combinations with oxygen and water, each of which would be regarded as the hydrated oxide of the particular compound radical; and hence they, in like manner, are called, by analogy, the *alcohols* of the bases to which they are allied, since they possess the properties just mentioned as characteristic of the class.

Alcohol is one of a numerous class of homologous bodies derived from carbide of hydrogen radicals, each differing in their composition by a definite number of elements of carbon and hydrogen. In giving rise to those bodies, it is found that the same number of equivalents of oxygen is appropriated by their respective radicals; and from this relation and their similarity in properties and composition, alcohol, as a general term, has been applied to the series: the propriety of the term will be seen on comparing the formulæ of a few of them:—

Radicals.		Oxides of radicals, or others.	Hydrated oxides of radicals, or alcohols.
Methyle, ...	$C_2\,H_3$	$C_2\,H_3\,O$	$C_2\,H_3\,O,\ H\,O$
Ethyle, ...	$C_4\,H_5$	$C_4\,H_5\,O$	$C_4\,H_5\,O,\ H\,O$
Amyle, ...	$C_{10}\,H_{11}$	$C_{10}\,H_{11}\,O$	$C_{10}\,H_{11}\,O,\ H\,O$
Propyle, ...	$C_6\,H_7$	$C_6\,H_7\,O$	$C_6\,H_7\,O,\ H\,O$
Ceryle, ...	$C_{54}\,H_{55}$	$C_{54}\,H_{55}\,O$	$C_{54}\,H_{55}\,O,\ H\,O$

Various other bodies are of a similar nature, differing only in the ratio of one or more equivalents of carbide of hydrogen—$C_2\,H_2$. Each of these alcohols may be converted into an acid by the substitution of two atoms of oxygen for two of hydrogen. Thus, there can be obtained from hydrated oxide—

Of Methyle,	$C_2\,H_3\,O,\ H\,O$,	formic acid,	$C_2\,H\,O_3,\ H\,O$;
Ethyle,	$C_4\,H_5\,O,\ H\,O$,	acetic acid,	$C_4\,H_3\,O_3,\ H\,O$;
Amyle,	$C_{10}\,H_{11}\,O,\ H\,O$,	valerianic acid,	$C_{10}\,H_9\,O_3,\ H\,O$;
Propile,	$C_6\,H_7\,O,\ H\,O$,	propylic acid,	$C_6\,H_5\,O_3,\ H\,O$;
Ceryle,	$C_{54}\,H_{55}\,O,\ H\,O$,	cerotic acid,	$C_{54}\,H_{53}\,O_3,\ H\,O$;

but the contrary process has never yet been effected, for we know of no method of converting acetic acid into wine-alcohol by replacing two equivalents of oxygen by two of hydrogen, and the same remark is applicable to the alcohols related to other carbides of hydrogen.

As art can *unite* carbon with oxygen, but has no means of effecting the disunion of the two when copulated, which nature is constantly doing, so it can replace hydrogen by oxygen in the alcohols, but is, as yet, incapable of achieving the converse process, by replacing the oxygen of the acid by an equivalent of hydrogen.

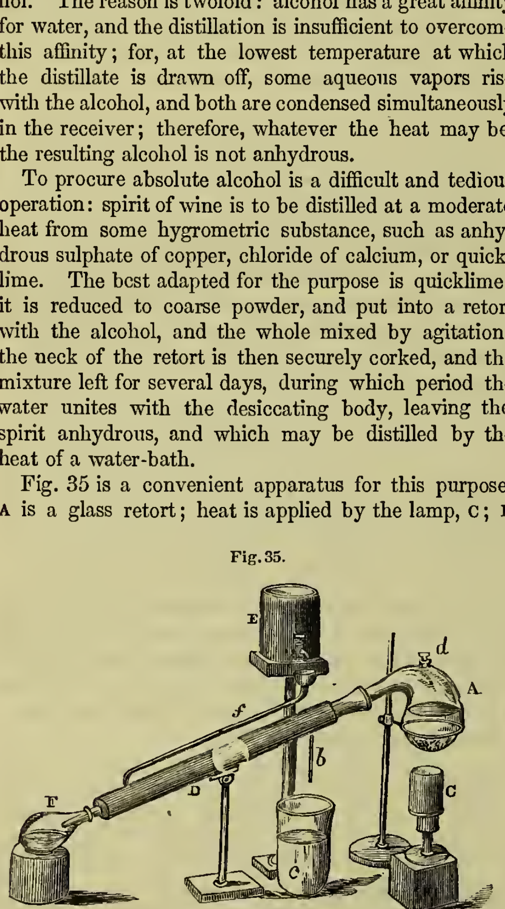
In a general and practical sense, by *alcohol* is understood the pure spirit obtained by distillation from all liquids which have suffered the vinous fermentation. It is the intoxicating principle of all vinous and spiritous liquors, as wine, brandy, whisky, *et cetera*. Distilled from wine, it bears the name—*spirit of wine*.

Alcohol is never produced except by the vinous or alcoholic fermentation of particular substances; and after the completion of such action, distillation of the fermented body affords it either in a concentrated or in a diluted state. By repeated rectifications the volatile spirit is procured, deprived of most of its accompanying water; but mere distillation, however long continued or often repeated, will not yield pure alcohol, that is, alcohol free from water—absolute alcohol. The reason is twofold: alcohol has a great affinity for water, and the distillation is insufficient to overcome this affinity; for, at the lowest temperature at which the distillate is drawn off, some aqueous vapors rise with the alcohol, and both are condensed simultaneously in the receiver; therefore, whatever the heat may be, the resulting alcohol is not anhydrous.

To procure absolute alcohol is a difficult and tedious operation: spirit of wine is to be distilled at a moderate heat from some hygrometric substance, such as anhydrous sulphate of copper, chloride of calcium, or quicklime. The best adapted for the purpose is quicklime: it is reduced to coarse powder, and put into a retort with the alcohol, and the whole mixed by agitation; the neck of the retort is then securely corked, and the mixture left for several days, during which period the water unites with the desiccating body, leaving the spirit anhydrous, and which may be distilled by the heat of a water-bath.

Fig. 35 is a convenient apparatus for this purpose. A is a glass retort; heat is applied by the lamp, C; D is the condenser, through which the tube receiving the beak of the retort passes to the flask, F. Cold water from the tank, E, enters the condenser, D, by the funnel tube, *f*, and the heated water is discharged by *b* into the vessel, *c*. The mouth of the receiver is closed by a perforated cork, to prevent the access of air, and the absorption of aqueous vapors. The dilute alcohol and coarsely-powdered desiccating compound, are introduced through the stoppered opening, *d*, the stopper replaced, and the distillation carried on at as low a temperature as possible—173° to 176° Fahr. Repeated distillations with fresh portions of lime or other hygroscopic substance are requisite, in order to free the alcohol from the last trace of water.

Fig. 35.



A singular but ingenious mode of concentrating alcohol is founded on the fact, that it does not moisten the animal tissues, but corrugates and abstracts water from them. This method was first employed by Soemmering to advantage. He used an ox or a calf-bladder, which was soaked for some time in water, and both freed from the fat and the attached vessels. After it is again inflated and dried, it is to be smeared over, the outside twice, and the inside four times, with a solution of isinglass, and then charged with diluted spirit, leaving a small space vacant. On exposing it to the heat of the sun in summer, or the heat of a stove, the water evaporates, while the alcohol remains. The air-bladders of fish answer the purpose equally as well as the bladders of oxen, and may, like them, be repeatedly used without injury. It is stated that, by placing the bladders filled with spirits to be concentrated over a sand-bath, with a proper degree of heat applied, absolute alcohol may be obtained in from six to twelve hours. Soemmering states he placed two bladders of the same size, having eight ounces of water in one and eight ounces of absolute alcohol in the other, over a sand-bath, where equal heat was communicated to both; after the lapse of four days, all the water was evaporated, and only one ounce of the alcohol.

Soemmering's process, although an interesting illustration of exosmose, is not practically applicable to the production of anhydrous alcohol; it is, however, an economical method, and particularly applicable in obtaining alcohol for the preparation of varnishes. Smugglers who bring spirits into France in bladders hid about their persons, have long known that although the liquor decreased in bulk, yet it increased in strength; hence the people prefer the article conveyed clandestinely.

Treating of the above, Donovan says he has never been able to obtain these results to the extent specified, nor, indeed, at all. He made the experiment on alcohol of varied strengths, with small and large bladders, with thick ones and thin ones; a diminution of strength was the invariable result, unless the spirit was very weak; whenever an increase of strength did happen, it was extremely trivial.

Graham has ingeniously proposed to concentrate alcohol as follows:—A large shallow basin is covered, to a small depth, with recently-burned lime, in coarse powder, and a smaller basin, containing three or four ounces of commercial alcohol, is made to rest upon the lime; the whole is placed under the low receiver of an air-pump, and the exhaustion continued till the alcohol evinces signs of ebullition. Of the mingled vapors of alcohol and water which now fill the receiver, the quicklime is capable of uniting with the aqueous only, which are, therefore, rapidly withdrawn, while the alcohol vapor is unaffected; and as water cannot remain in the alcohol as long as the superincumbent atmosphere is devoid of moisture, more aqueous vapor rises, which is likewise abstracted by the lime, and thus the process goes on till the whole of the water in the alcohol is removed. Several days are always required for this purpose, and in winter a longer time than in summer. On submitting alcohol of spec. grav. 0·827 to dehydration by this method, the following are the notes of the decreasing specific gravity after every twenty-four hours:—

When the liquid was introduced, the density was	0·827
Density after twenty-four hours' exposure to the action of the caustic lime, ...	0·817
Do. after second twenty-four hours, ...	0·808
Do. after third do.	0·802
Do. after fourth do	0·798
Do. after fifth do.	0·796

The longer time required for the concentration of the spirit in the winter season is seen from the following table, where the liquid, before enclosing it under the air-pump with the lime, had a spec. grav. 0·825:—

On determining the specific gravity after twenty-four hours, the result was	0·817
Do. after the second twenty-four hours,....	0·809
Do. after the third do.	0·804
Do. after the fourth do.	0·799
Do. after the fifth do.	0·797
Do. after the sixth do.	0·796

Quicklime possesses the property of uniting with a portion of alcohol vapor, and for this reason should not be used in great excess. Graham found, that when four ounces of ordinary alcohol were exposed to the action of the lime, under the bell-jar of the air-pump, one-sixth of the alcohol was lost, on account of the absorption by the quicklime. Hence the quantity of lime used should never exceed three times the weight of the alcohol, otherwise the loss of alcohol will become appreciable; the lime should be spread to as great an extent within the receiver as possible, that a larger absorbing surface may be presented to the vapor. This process could be advantageously employed in concentrating alcohol on the large scale, by taking an air-tight box, of any suitable size, provided with a number of shelves, on which powdered quicklime might be strewn, and the alcohol, contained in a number of basins, placed upon it. The apparatus might be sufficiently exhausted by a syringe, as a complete vacuum is not required. Besides these little attentions, nothing further would be requisite than to open the box at the termination of a week or ten days, and examine whether the alcohol had attained the proper density.

Alcohol may be concentrated by exposing it with lime in a close vessel, but it requires a considerably longer time; it cannot be concentrated over strong sulphuric acid, for this acid absorbs alcohol vapor with the same affinity with which it unites with water, and the heat produced is very great: a temperature of 500° to 600° Fahr. is not capable of eliminating the whole of the spirit from the mixture. Sulphuric acid diluted with water loses its property of absorbing alcohol vapor. Chloride of calcium is not well adapted for concentrating alcohol, on account of the affinity existing between these two bodies: when they are submitted to distillation, the aqueous vapor absorbed by the chloride of calcium goes over with the last portions of the alcohol; it can, however, be advantageously employed, if the process be arrested when half the quantity of spirit has accumulated in the receiver.

Drinkwater, in his investigation on the preparation of absolute alcohol and the composition of *proof spirit*, procured alcohol of the lowest specific gravity hitherto obtained. The mode of procedure was as follows:—Carbonate of potassa was exposed to a red heat, to deprive it of water, and, when sufficiently cool, was pulverized and added to ordinary alcohol, of spec. grav. ·850, at 60° Fahr., till it ceased to dissolve any more; the menstruum was then allowed to digest twenty-four hours, being frequently agitated, and the alcohol carefully separated by decantation. As much fresh-burned quicklime as was considered sufficient, when powdered, to absorb the whole of the alcohol, was introduced into a retort, and the alcohol added to it; after digesting forty-eight hours, it was slowly distilled in a water-bath at a temperature of about 180° Fahr.

The alcohol thus obtained was carefully redistilled, and its specific gravity, at 60° Fahr., was found, in two experiments, to be ·7946 and ·7947; agreeing very nearly with the determination of Rudberg, which has been adopted by Gay-Lussac and others, *videlicet*, ·7947, at 59° Fahr. With a view, however, to discover whether it was possible, by means of lime, to abstract any more water from the alcohol, the retort was again filled with fresh-burned and pulverized quicklime, and the same alcohol mixed with it; the mixture was then allowed to digest a whole week, at the ordinary temperature of the laboratory—about 60° Fahr.

After this lapse of time, the alcohol was distilled off as before, and the distillate submitted to a second operation, which was conducted very slowly at first—at the rate of about one drop in ten seconds, the heat of the water-bath being 165° Fahr. Distillation was continued till about the one-twentieth of the whole had passed over, the object being to allow any minute quantity of water which the alcohol might still retain, to evaporate or diffuse itself into the atmosphere of absolute alcohol above it; the process was then continued rapidly, the heat of the bath being increased to 180° Fahr., till about one-twentieth more had passed over; the receiver was then changed, and the latter portions slowly eliminated. The specific gravity of the alcohol, taken twice, was ·7944, at 60° Fahr. As a further test of its purity, it was divided into two equal parts; one part was again digested on quicklime, and the other on sulphate of copper deprived of water by heat, the method of operation being as follows:—

Firstly: Some lumps of freshly-burned quicklime were heated to a red heat, and quickly pulverized and introduced into the tin boiler of a small still, which was partly immersed in water, to prevent the melting of the solder. This vessel was completely filled with quicklime, and kept corked till sufficiently cool, when the alcohol was added; but it being comparatively small in quantity, the lime appeared perfectly dry: the vessel was then closely corked.

Secondly: A quantity of sulphate of copper was exposed to a red heat, to deprive it of all water; it was then very quickly ground and thrown into a small tin cucurbit, and when cold, the alcohol—insufficient to cover it—was added, and the vessel tightly corked.

These vessels, with their contents, were kept at the ordinary temperature of the laboratory for four days; they were then partially immersed in a water-bath, and kept at a temperature of about 150° Fahr., for forty-eight hours, after which the alcohol was distilled and redistilled with all the precautions before mentioned; the temperature of the water-bath, on the redistillation, never exceeded 172° Fahr., and the first tenth part was put aside in each case as possibly impure. Subjoined are the specific gravities of the alcohol thus obtained:

	Alcohol distilled from the dry cuprosulphate.	Alcohol distilled from the quicklime.
I.,	0·79470	0·79409
II.,	0·79472	0·79412

These experiments prove that anhydrous sulphate of copper is not so effective as quicklime for removing the last traces of water from alcohol. It was, however, generally observed, that the specific gravity of the alcohol gradually increased, probably from its hygrometric property, by which it absorbed a minute quantity of moisture from the air on being transferred from one bottle to another; and thinking, consequently, that a small quantity of moisture might have been abstracted from the atmosphere during the distillation—which was conducted in the usual way—and the specific gravity thus slightly increased, the operator considered it desirable to make another experiment, in which this source of error should be guarded against, by conducting the distillation, as much as possible, out of contact with the external air, and, with that view, proceeded as follows:—The different portions of alcohol before obtained were mixed together, when the specific gravity was found to be 0·7947; this alcohol was again digested at a temperature of about 150° Fahr. for fourteen days with quicklime previously heated to redness, as in the former experiment; it was then slowly distilled, out of contact with the external atmosphere, by means of a tube which passed from the condenser through a cork into the bottle in which it was to remain—the temperature at which it was distilled being 175°—and the first tenth part was put aside as possibly containing a minute quantity of water; the remainder was then distilled off at 178° to 180° Fahr. This alcohol was quickly transferred to a dry retort, and redistilled in a similar way, at a water-bath heat of 172°; the first tenth part was set aside, and the remainder kept as pure anhydrous alcohol, or as free from water as it is possible to obtain it by this process. The specific gravity was taken the next day with all the precautions before mentioned, the alcohol being also kept, during the time of transference, as much as possible out of contact with the air, when the results of four trials were as annexed:—

Temp. of room, 60° Fahr. Barometer, 29·810 inches.

I.,	·793836
II.,	.793806
III.,	·793798
IV.,	·793804
Mean,	·793811

A portion of this alcohol was subsequently digested with quicklime for three months, it was then distilled, and its specific gravity was found to be exactly the same as before. Hence one may conclude, with tolerable certainty, that 0·79381 expresses the specific gravity of absolute alcohol at 60° Fahr.

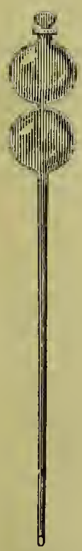
A very excellent method for the preparation of pure alcohol is recommended by Poggendorff.—Dissolve as much potassa in alcohol as it will take up, then add half its volume of water, and distil at a low temperature; a perfectly pure product is the result. On account of the high price of caustic potassa, this method cannot be applied on the large scale; but when a small quantity only is required for laboratory purposes, it is the surest way to obtain a perfectly pure product.

Properties of Alcohol.—Pure anhydrous, or absolute alcohol, is a limpid colorless liquid, of a greater fluidity than water, having a penetrating but agreeable odor, and a hot pungent taste, owing to its abstracting water from the tissue of the tongue. The great affinity of alcohol for water is the cause of its poisonous action on the system, since it destroys the vital functions of the tissues by abstracting their constitutional moisture with avidity; these violent effects are not produced when alcohol, in a diluted state, is taken in small quantities—only a pleasant hilarity follows, though larger draughts are succeeded by stupor and intoxication. It is a powerful stimulant and antiseptic. At moderate temperatures, neither atmospheric air nor oxygen gas has the slightest action upon alcohol, whether in the liquid or gaseous form; but at elevated temperatures the case is different. Alcohol, when anhydrous, burns with a whitish flame, which deposits carbon on a cold surface held in it; the flame is quite blue when it is mixed with water, and no deposit of carbon is formed. In the combustion of alcohol, very little light is emitted, but intense heat is given off: Boerhaave first showed, that when the vapor which escapes during the combustion is collected in proper vessels, it is no other than water. If alcohol be burned by a wick surrounded by a spiral of platinum wire, and the flame be suddenly extinguished, the platinum wire continues to incandesce—a phenomenon caused by the imperfect combustion of the alcoholic vapors; aldehydic acid is formed, a body possessing a pungent and disagreeable smell. Platinum black moistened with alcohol, becomes incandescent, but if much alcohol is added, so as to prevent the elevation of the temperature, oxygen is absorbed, and the alcohol is converted into aldehyde, *et cetera.* Alcohol is exceedingly volatile: if a few drops be introduced into a jar of oxygen gas, it is readily converted into vapor, and a very explosive mixture is produced. When one volume of alcoholic vapor and three of oxygen are mixed, and ignited by the electric spark, a violent explosion ensues, and two volumes of carbonic acid and three volumes of aqueous vapor are formed.

Alcohol requires an intense cold to effect its freezing. Dr. Mitchell, of Philadelphia, who, by evaporation of solid carbonic acid and ether, *in vacuo,* has produced very great cold, found that alcohol of spec. grav. 0·798 became oily and adhesive at —130°; by a greater cold it became still thicker, and at —146° it flowed like melted wax. Alcohol of spec. grav. 0·820 froze easily.

Faraday exposed alcohol to a temperature of 166° Fahr. below zero; it thickened, but did not congeal. Hence the great use of spirit thermometers when a very low temperature is required to be noted. Löwig, however, recently stated, that anhydrous alcohol congeals at a temperature of 144·5° Fahr. below zero, in opposition to the above statement of Faraday. The specific gravity of absolute alcohol is given in most chemical works as 0·7949; but from Drinkwater's experiments, before alluded to, and which were conducted with every precaution, the spec. grav. is 0·793811; it boils at 173°, at a barometric pressure of 29·5 inches. It has a powerful affinity for water; hence the necessity of keeping it in ground stoppled bottles to preserve it anhydrous. When mixed with water, much heat is produced, and a diminution in volume takes place. This is illustrated by the annexed woodcut—Fig. 36—which consists of a long tube of glass, furnished with two bulbs on the upper part, and having the elongated neck of the higher bulb closed perfectly with a ground glass stopple. The tube and lower bulb are filled with distilled water; when this is effected, alcohol is poured in till the upper bulb is filled; the stopper is next replaced, and the tube gently inverted. The two liquids now combine, and an empty space is visible, which, before combination, was completely filled. The space unoccupied shows the amount of contraction in bulk which has arisen from the combination of the alcohol and water; an elevation of temperature also takes place, in consequence of the chemical combination and the diminished specific gravity of the mixture. Thus, equal measures of alcohol, of spec. grav. 0·825, and water, each at 50° Fahr., afford, when suddenly mixed, a temperature of 70°; and a mixture of equal parts of proof spirit and water, at 50°, give, under the like circumstances, a mixture having a temperature of 60° Fahr. If alcohol and ice are mixed, the temperature is considerably lowered. Absolute alcohol, with a little more ice than it will dissolve, reduces the temperature as low as —35° Fahr. Spirit of wine, of spec. grav. 0·86, and 61° temperature, mixed with snow at 32°, is cooled down to —14° Fahr. The contraction arising from the admixture of alcohol and water, increases regularly till the liquid consists of one atom of alcohol and three atoms of water, or, by weight, of 100 parts of alcohol to 116·24 parts of water. One hundred volumes of this mixture, at 59° Fahr., is composed of 53·94 volumes of anhydrous alcohol, and 49·84 volumes of water; hence the contraction is 3·78 volumes, and the specific gravity of the mixture is 0·927 at 59°.

Fig. 36.



Thillaye shows that the mixture, when water is present in excess, or beyond a certain limit, expands sensibly; besides, his experiments prove, that when three volumes of alcohol, of spec. grav. 0·954, are mixed with seven of water, the mixed solution has a spec. grav. of 0·9850, whereas the calculated specific gravity should be 0·9863, thus indicating a decrease of gravity and a corresponding increase of volume, amounting to ·0013. This expansion, however, is only apparent, on account of the heat which is generated; but if the mixture were made of absolute alcohol and water till the specific gravity became 0·985, instead of an expansion, a contraction of 0·007 would be observed.

The following table, from the calculation of Gay-Lussac's experiments by Rudberg, shows the contraction of every decreasing five per cent. in the content of alcohol :—

Per cent., in volume, of absolute alcohol in 100 volumes of mixture at 59°.	Contraction, in per cent., of the volume of the mixture.	Per cent., in volume, of absolute alcohol in 100 volumes of mixture at 59°.	Contraction, in per cent., of the volume of the mixture.
100	0·00	50	3·74
95	1·18	45	3·64
90	1·94	40	3·44
85	2·47	35	3·14
80	2·87	30	2·72
75	3·19	25	2·24
70	3·44	20	1·72
65	3·61	15	1·20
60	3·73	10	0·72
55	3·77	5	0·31

From this table it will be observed, that the contraction is the same with mixtures containing different amounts of alcohol; for example, with the mixture containing seventy per cent. of alcohol and that containing forty per cent. the contraction is 3·44. The reason is evident: the contraction increases to a certain point, and then decreases as the proportion of absolute alcohol lessens, giving to the intermediate mixtures, between the maximum and minimum points, a corresponding degree.

The volatility of alcohol is generally affected by admixture with water, as well as its specific gravity and expansive force. Tralles found, that small quantities of water mixed with alcohol do not sensibly raise the boiling point of the liquor beyond that of pure alcohol, and Soemmering has shown that a mixture of alcohol with about three per cent. of water has greater volatility than absolute alcohol, and that a spiritous liquor compounded of ninety-four per cent. of absolute alcohol and six of water, possesses the same volatility as alcohol of 0·7947. Further, according to Soemmering, when alcohol of 0·7947 density is mixed with water till the specific gravity becomes 0·8, and distilled, those portions which first pass off are saturated with water, and the alcoholic solution in the retort becomes richer, till, in the end, absolute alcohol passes over; on the contrary, when the mixture contains over six per cent. of water, the first portions of the distillate are richest in alcohol, and afterwards they become weaker to the end of the operation—the temperature also rises as the alcohol is expelled, gradually approaching to that of boiling water, and actually attaining that point at the close of the process, when all the spirit is driven over.

Taking advantage of this property, an attempt has been made to give the strength of various mixtures of alcohol and water, by ascertaining the temperature of the vapor, for which purpose Groening has constructed the following table. It consists of three columns: the first shows the temperature; the second, the quantity of alcohol in the boiling solution; and the third, the quantity of alcohol in the vapor evolved:—

Temp.	Per cent. of alcohol in the boiling liquid in the retort.	Per cent. of alcohol in the distillate.	Temp.	Per cent. of alcohol in the boiling liquid in the retort.	Per cent. of alcohol in the distillate.
171°	92	93	189·5°	20	71
158·9	90	92	191·8	18	68
172	85	91·5	194	15	66
172·7	80	90·5	196·3	12	61
173·8	75	90	198·5	10	55
175·1	70	89	200·8	7	50
176	65	87	203	5	42
178·3	50	85	205·3	3	36
180·5	40	82	207·5	2	28
182·8	35	80	209·8	1	13
185	30	78	212	0	0
187·3	25	76			

The elastic force of alcohol-vapor is very great; the following table, showing the elastic force from 32° Fahr. to 264°, is given in the Philosophical Transactions for 1818. The specific gravity of the alcohol was 0·813.

Temp.	Force of vapor.	Temp.	Force of vapor.	Temp.	Force of vapor.
32°	0·40	135°	12·15	216°	72·20
40	0·56	140	13·90	220	78·50
45	0·70	145	15·95	225	87·50
50	0·86	150	18·00	230	94·10
55	1·00	155	20·30	232	97·10
60	1·23	160	22·60	236	103·60
65	1·49	165	25·40	238	109·90
70	1·76	170	28·30	240	111·24
75	2·10	173	30·00	244	118·20
80	2·45	178·3	33·50	247	122·10
85	2·93	180	34·73	248	126·10
90	3·40	182·3	36·40	249·7	131·40
95	3·90	185·3	39·90	250	132·30
100	4·50	190	43·20	252	138·60
105	5·20	193·3	46·60	254·3	143·70
110	6·00	196·3	50·10	258·6	151·60
115	7·10	200	53·00	260	155·20
120	8·10	206	60·10	262	162·40
125	9·25	210	65·00	264	166·10
130	10·60	214	69·30		

The expansion of alcohol by heat is not uniform; a thousand measures, spec. grav. 0·817, become one thousand and seventy-nine when heated from 50° to 170° Fahr. At a medium temperature the expansion is a little below the true mean; but with the state of dilution of the alcohol this difference between both ends of the scale becomes more marked. The greatest uniformity of expansion is between —14° and +98°, being about 0·00047 of its volume for every degree. The contraction of alcohol from its boiling point, 173° Fahr., has been investigated by Gay-Lussac, who gives the condensation of one thousand volumes in every 9° Fahr., or 5° C., from the boiling point of the liquid.

Temperature.		Volume of alcohol.	Temperature.		Volume of alcohol.
Centigrade.	Fahrenheit.		Centigrade.	Fahrenheit.	
74·14°	173°	1000·0	38·4°	101°	954·3
73·4	164	994·4	33·4	92	949·1
68·4	155	988·6	28·4	83	944·0
63·4	146	982·5	23·4	74	939·0
58·4	137	975·7	18·4	65	934·0
53·4	128	970·8	13·4	56	929·3
48·4	119	965·3	8·4	47	924·5
43·4	110	969·7	3·4	38	919·9

One volume of alcohol yields 488·3 volumes of vapor at 212° Fahr.; compared with water at the same temperature, the volume of alcoholic vapor is greater in the ratio of 3·14 to 1·00. The specific gravity of the vapor of absolute alcohol, taking air as unity, was found by Gay-Lussac to be 1·6133. On the assumption that it is composed of one volume of aqueous vapor and one volume of olefiant gas condensed into one volume of vapor of alcohol, the density by calculation would be 1·6070; Berzelius, however, gives the density at 1·6004. According to Despretz, the latent heat of the vapor, on being compared with that of water, is as 332 to 351.

Alcohol vapor, when transmitted through a red-hot tube, is decomposed: Saussure found that, on passing it slowly through a porcelain tube heated to redness, a little carbon was deposited on the interior of the tube, together with a volatile crystalline substance—naphthaline—and a brown empyreumatic oil; the gaseous products were carbide of hydrogen, carbonic oxide, and hydrogen. M. Berthelot passed alcohol vapor through a porcelain tube filled with pumice, and heated to redness. He obtained carbon, carbides of hydrogen, aldehyde, naphthaline, benzine, phenic acid, *et cetera.*

The analysis of alcohol by Saussure, Dumas, and others, shows that it consists of—

	Atomic weight.	Per cent.
4 Eqs. of carbon,	24	52·18
6 Eqs. of hydrogen,	6	13·04
2 Eqs. of oxygen,	16	34·78
	46	100·00

Formula:—$C_4 H_6 O_2 = C_4 H_5 O, H O$.

This formula of alcohol is confirmed by the composition and density of its vapor, as calculated from the density of the above constituents, *videlicet*—

	Density.
8 Volumes of carbon vapor,	3·372
12 Volumes of hydrogen vapor,	0·825
2 Volumes of oxygen vapor,	2·205
Equal four volumes of alcohol vapor,...	4) 6·402
Density of vapor of alcohol,	1·6005

Alcohol possesses the property of absorbing gases even in a higher degree than water. Considerable experiments had been instituted by Saussure on this subject, from whose results the following table has been formed:—

There is absorbed at 61·4°, of	By 1 volume air-free water.	By 1 volume air-free alcohol. sp. gr. 0·84.
	Volumes.	Volumes.
Sulphurous acid gas,	43·78	115·77
Sulphide of hydrogen,	2·53	6·06
Carbonic acid,	1·06	1·86
Nitrous oxide,	0·76	1·53
Olefiant gas,	0·155	1·27
Oxygen,	0·065	0·1625
Carbonic oxide,	0·062	0·145
Hydrogen,	0 046	0·051
Nitrogen,	0·042	0·042

About sixty-eight volumes of hydrochloric acid gas are absorbed by alcohol, as also binoxide of nitrogen, nitric oxide, and cyanogen in considerable quantities.

Most of these gases are evolved when the saturated spirit is boiled or exposed to the air, while others, such as hydrochloric acid gas, nitrous acid, *et cetera*, decompose the liquid.

Alcohol is one of the best solvents which the chemist possesses, but by dilution with water this property is much diminished. Sulphur is dissolved by it in the heat; but is deposited again in small crystals as the solution cools. An alcoholic solution of sulphur becomes turbid when diluted with water, and evolves a peculiar hepatic odor; and, like all soluble sulphides, precipitates metals from the solution of their oxides in acids, as sulphides. Phosphorus is also dissolved by alcohol, for which **Buchner** states that three hundred and twenty parts of cold, and two hundred and forty parts of hot alcohol are required. From the latter solution, one-fourth of the quantity of phosphorus deposits as it cools.

Chlorine and bromine decompose alcohol, giving rise to chloral and bromal, and hydrochloric and hydrobromic acid. Iodine is dissolved by alcohol, and forms a brown colored solution; if hot alcohol be employed, the iodine is deposited in crystals after some time, and hydriodic acid is formed in the liquid. If to a solution of iodine in alcohol, potassa-alcohol be added till the menstruum becomes colorless, iodide of potassium and *iodoform* are synchronously produced, as expressed in the subjoined equation:—

$$\underbrace{C_4H_6O_2}_{\text{Alcohol.}} + \underbrace{4I}_{\text{Iodine.}} + KO + O_6$$

Equal—

$$\underbrace{C_2HI_3}_{\text{Iodoform.}} + \underbrace{2CO_2 + KI}_{\text{Iodide of potassium.}} + 5HO.$$

By a corresponding decomposition, when distilled with hypochlorite of lime, or bleaching powder, it gives *chloroform*. Concentrated chloric, bromic, and nitric acids react violently upon alcohol, giving rise to acetic acid and a number of other bodies. This reaction is sometimes so energetic as to cause combustion. A mixture of very weak sulphuric acid and peroxide of manganese, when distilled with spirit of wine, affords principally aldehyde; acetic and formic ether are also formed, and towards the end of the distillation a weak solution, containing acetic and formic acids, passes over.

Pure chromic acid acts upon alcohol, giving rise to aldehyde and sesquiacetate of chromium. Sulphuric acid, with moderately dilute alcohol, gives rise to ether, as also do phosphoric and arsenic acids; even selenious acid, on being distilled with that liquid, causes the formation of ether. On distilling a mixture of selenious acid, sulphuric acid, and alcohol, the distillate emits a most horrible odor—hydroselenic acid—and selenium deposits in the retort. Acetic, oxalic, formic, hydrochloric, hydrobromic, and hydriodic acids, decompose alcohol, giving rise to ethers. Fluoride of borium acts upon alcohol in the heat, forming hydrofluoboric acid, boracic acid, and ether. Chloride of antimony, sesquichloride of iron, bichloride of tin, *et cetera*, decompose alcohol, forming oxides and hydrochloric ethers. Potassium behaves with alcohol as with water.

Graham has shown that alcohol combines with most salts, forming with them peculiar compounds—alcoates—analogous to hydrates. A great many of the neutral salts are soluble in alcohol; in general, all deliquescent salts, excepting the carbonate of potassa, are soluble in alcohol, and those inorganic compounds which are only sparingly soluble in water, also prove insoluble in that liquid.

Alcohol is peculiarly adapted for dissolving copal, mastic, and a great number of resins which are employed in the preparation of the finest varnishes. The fats and volatile essential oils are likewise dissolved by it, and are employed with balsams in the composition of an extensive class of elixirs, tinctures, and quintessences.

Sir **Humphrey Davy** discovered that a fine platinum wire, heated to redness, and held in the vapor of ether, continued ignited for some time. Mr. **Gill** has practically applied this discovery, in the formation of an alcohol lamp—lamp without flame—of the following construction. A cylindrical coil of thin platinum wire is placed, part round the cotton wick of a spirit lamp, and part above the wick, and the lamp lighted to heat the wire to redness; on the flame being extinguished, the alcoholic vapor keeps the wire red-hot for any length of time, according to the supply of the spirit, and with a very small expenditure thereof, so as to be in constant readiness to ignite tinder or a lucifer match. The proper size of the platinum wire is the hundredth part of an inch, which may be easily ascertained by coiling ten turns of the wire on a cylinder, and if they measure the tenth of an inch it will be right. A larger size only yields a dull red light, and a smaller one is difficult to use; about twelve turns of the wire will be sufficient, wrapped round any cylindrical body suited to the size of the wick of the lamp—and four or five coils should be placed on the wick, and the remainder of the wire above it.

A lamp constituted as above will require about half an ounce of alcohol to keep it in readiness for eight hours. This lamp affords sufficient luminousness to show the hour of the night by a watch, and to perform other useful services. As the Literary Journal remarks, its constantly keeping a uniform heat, and not requiring snuffing like other lamps, might make it a valuable acquisition to the chemist for experiments on a small scale, where a long continuance of a feeble heat is desirable. This suggestion may be acted upon where gas is not to be had. It would do well in Germany, where alcohol is very cheap; but the enormous price of alcohol in this country is an effectual bar to its extensive employment.

The following apposite remarks, showing the importance of having this valuable spirit exempted from duty for manufacturing purposes, the Editor deems worthy a place here. It would be impossible to name an article, says the Chemist, the duty on which is productive of so much injury to science and industry. Alcohol is the menstruum by means of which the various proximate principles of the vegetal kingdom are separated; and by which the Pharmacopolist furnishes the medical profession with those active principles on which the properties of vegetal medicines depend. On the present occasion, however, it is not the Editor's intention to dwell on this portion of the subject, but to consider those bodies which owe their origin to alcohol, commencing with chloroform.

It is calculated by manufacturers, that one gallon of alcohol, of spec. grav. ·830 to ·840, will produce two and a half pounds of chloroform—some obtain a little more. This gallon of spirit costs about seventeen shillings and sixpence, of which about ten shillings are for duty. The two and a half pounds will not sell for more than seventeen shillings—less than the cost of the spirit, and allowing nothing for the expense of hypochlorite of lime and labor. The reason that chloroform is sold in England at a lower price than the cost of its production there, is, that in Scotland the duty on alcohol is very considerably lower than in England, and that there is no duty on chloroform brought from the former country to the latter. The Scottish manufacturer is thus enabled to undersell the English in his own market.

The duty charged on alcohol amounts to about four shillings per pound on the chloroform produced from it, or nearly two-thirds of its value; the effect of this state of things is, that the manufacturer has endeavored to employ substitutes for alcohol in the manufacture; and chloroform so produced is occasionally met with in the market. Every one acquainted with the subject must admit, that chloroform, made from such a substitute as pyroxylic spirit, is less safe for employment in medical practice, and is, at any rate, far more disagreeable than that prepared from alcohol. It has been alleged, that the injurious effects that have followed the use of chloroform as an anæsthetic agent, have been traced to the fact of its having been prepared from pyroxilic spirit.

From the peculiar qualities of chloroform—its powerful solvent properties on certain gums, and the ease with which it volatilizes—there is no doubt that, if it could be produced at a moderate price, it would soon be applied to a variety of useful purposes in the arts; but, under existing circumstances, the honor and profit of such application are left to other nations, where genius is less fettered by fiscal restrictions. It is necessary to impress on the public mind, that the duty on alcohol acts as a prohibition to its use in industrial pursuits; that it would be a matter of policy in the Government to place the English manufacturer on an equality with the Scotch and the foreigner, and that the imperial coffers are not enriched by the enforcement of this tax, which inflicts such severe injury on the industrious classes. It is very true, that, in the instance of chloroform, England is supplied from Scotland; but there are many cases in which Great Britain sends to foreign countries for those articles in which alcohol performs an important part, and in which she might enjoy a considerable trade of her own.

The Chemist concludes the article as follows:—A gallon of ordinary rectified spirit produces about four pounds of commercial ether, and upon this foundation is based the extra amount of duty which is to be paid upon it when brought to England from those parts of the United Kingdom in which the duty is lower; still, it is a well-known fact, that ether may be obtained in the English market at the bare cost of the duty, namely, two shillings and sixpence per pound. There can be no doubt that, if Government does not relieve from the present duty that portion of spirit, at least, which is used for manufacturing purposes, an attempt will be made to charge upon chloroform the extra amount of duty, as in the case of ether, *et cetera*, chloroform having become an article of commercial importance.

The English manufacturer wants to be permitted to use alcohol, duty free, for manufacturing purposes; and there is no sufficient reason why he should not have this opportunity, nor why he should be compelled to seek substitutes. It cannot be expected that any manufacture in which alcohol is so important an element as in chloroform and ether, can thrive when so excessive and exorbitant a duty is charged on it. The application of these compounds to many useful purposes, is retarded or prevented by it.

ALCOHOLIC LIQUORS—WHISKY.—The subjoined historical remarks form an appropriate introduction to the manufacture of whisky:—Spiritous liquors have been noticed in some of our earliest songs and writings; and the English, shortly after the invasion, in the time of HENRY II., found the Irish people indulging in potations of this liquor. History informs us that the knowledge of *aqua vitæ* was first acquired in Europe in the reign of that monarch; but it is more than probable that the Irish were acquainted with it before the English. The strong similarity between the Irish language and the primitive languages of Asia, as stated by eminent etymologists, and the intercourse the Irish had with that quarter of the world, lead to the supposition that the art of distillation was introduced directly from India; but it is more likely that it was received from Spain or Italy, where it was early known under the epithet of *acqua vite*, or *acqua di vite*—water of the vine—as the spirit was originally extracted in those countries from the grape. The monasteries being the archives of science, and the original dispensaries of medicine, it is a natural surmise that the term *acqua vite* was there corrupted into the Latin and universal appellation, *aqua vitæ*—water of life—from its salutary and beneficial effects as a medicine; and from the Latin tongue being the general conveyancer of scientific discovery, as well as of familiar correspondence, the term *aqua vitæ* may have crept into common use to signify an indefinite distilled spirit, in contradistinction to *acqua vite*, the mere extract of the grape. The dissolution of the monasteries gave the secret of this invention to the public, and the elixir of the alembic soon attained the summit of popular regard.

CAMPION relates, that when the new settlers were attacked by any of the diseases common to the country, they used *aqua vitæ*, or *usquebaugh*, the ordinary beverage of the inhabitants, as the best restorative of health, and chief preventive of contagion. Speaking of a famine which happened in 1316, he says it was caused by the soldiers eating flesh and drinking *aqua vitæ* in Lent. It would seem that *aqua vitæ* was employed in Ireland, at one time, as opium has been amongst the Turks, to inspire heroism; and this is exemplified in the case of a knight, named SAVAGE, who lived in 1350, and, previously to entering the field of battle, ordered to each soldier a mighty draught of *aqua vitæ*. One learns from WARE and ZEDWICK, that the *aqua vitæ* or *usquebaugh* of the Irish was of a less inflammatory nature than that made in England, because the latter is supposed to be of more recent invention. Its virtues, and the directions for making it, both simple and compound, are recorded in the Red Book of OSSORY, a work compiled about five hundred years since, and which, likewise, contains a receipt for making another liquor termed *nectar*, composed of a mixture of honey and wine, having ginger, pepper, cinnamon, and other ingredients, incorporated. This mixture was called *piment*, from its pungency and spicy nature, and on account of its delicious quality it was much celebrated by the early French poets, who considered the perfuming of wine with foreign aromatics, then so dear and difficult of procuring, as the very acme of taste and ingenuity. In Ireland, it was an early practice to imitate foreign liqueurs, which, from the praise of the poets alluded to, must have even excelled those of Italy and France. *Aqua vitæ* was first used in the country as a medicine, and was considered as a panacea for all disorders; the physicians recommended it to patients indiscriminately, for preserving health, dissipating humors, strengthening the heart, curing colic, dropsy, palsy, *et cetera*, and even prolonging existence itself beyond the common limits! Hence it was eagerly sought, and the taste, thus formed, has been transmitted from generation to generation, and to which many adhere with an attachment rather strengthened than diminished by long custom.

The Latin epithet, *aqua vitæ*, the Irish term, *usquebaugh*, and the modern word, whisky, are, in point of fact, synonymous; *aqua vitæ*, signifying the *water of life*, and *usquebaugh*, which should be written *iskebaghah* or *isquebeoh*, the former implying *water of life*, and the latter *living water*. As *isque*, or *iske*, in the Irish dialect, means water, it must appear evident that the term whisky is only a slight alteration in the pronunciation of this term. O'BRIEN and VALLENCEY both admit that *ai*, *ay*, or *ey*, are old terms for water, and *isque*, or *iske*, implying water, the compound word literally means *water of waters;* the word whisky, therefore, is of very comprehensive import, and fully expressive of this sense-subduing beverage.

It is not easy to determine the origin of the term *aqua vitæ*, as applied to exhilarating liquors, unless by an admission of the reasoning already advanced.

Having thus far entered into the history of the subject under review, the manufacturing processes will be prefaced, by an intelligent visitor, with the routine, arrangements, *et cetera*, of an extensive London distillery. He writes:—The first objects that met the eye were large granaries, or magazines, in which the grain was stored; beyond these appeared various buildings, connected with the still-room, containing a huge cylindrical worm-tub, water-tanks, and refrigerating tanks, *et cetera.* Near the entrance were the *mill* and the *brewhouse*, for conducting all those preliminary operations preceding the actual distillation. The open court presented a bustling scene—waggons bringing in yeast from the great London breweries, others laden with casks destined for different parts of the metropolis; a number of carts were conveying grain to the dairies, and at another part of the premises men were employed filling barrels with spent wash, to be sent to the fatteners of cattle and swine.

The operations of a *distillery* relate to the extraction of the alcohol from various sorts of grain. Wheat, oats, barley, rye, Indian corn, rice, and other of the *gramineæ*, whether in the raw or in the malted state, as well as the juices of fruits, sugar-cane, beet-root, potatoes, carrots, and even some of the *grasses*, and many other vegetal and natural substances, eviscerate certain elements, which, by peculiar processes, yield alcohol. Distillation is invariably one of these operations, but it is preceded by others which differ according to the nature of the ingredients employed. Those liquors universally known and abused, such as whisky, hollands, gin, brandy, rum, spirits of wine, and cordials of various kinds, all contain alcohol, which passes over in the process of distillation. British brandy, British gin, whisky, or rum, are produced from corn; French brandy, from wine; West Indian rum, from sugar or molasses. The different qualities of these various liquids depend partly on the centesimal amount of alcohol, partly on the berries, herbs, and seeds with which they are flavored, partly on their mode of manufacture, and lastly, on the substances whence they are derived. In every case, however, the substance suffering the process of distillation is a *sweet* liquid, but the means whereby the saccharine material is instituted, vary with circumstances. The extract produced from grain is converted into a kind of beer before being distilled. The fermented liquor, modified in a particular way, forms *beer* at the brewery; whilst, in the distillery, it is known under the name of *wash*, and is that liquid which undergoes, subsequently, the process of distillation.

All the grain goes through the granary, and, when required in meal, passes into the mill-room, which contains several pair of millstones, ranged in a circle, and worked by a large steam-engine. The meal next goes to the brewhouse, in which are large coppers for heating water, and prodigious mash-tuns, capable of holding many thousand gallons. Here it is mashed, and its residue sold to the cattle-feeders.

The coolers, or cooling floors, occupy the upper portion of a building adjoining the brewhouse. These floors are covered with iron plates, three or four feet square, and are joined edge to edge. Raised ledges are placed across the floors, at certain distances, to divide them into compartments; and into the shallow cells or trays thus formed, the hot wort is introduced. The whole of the immense floor, one hundred and fifty feet in length, becomes covered with a stratum of hot liquor, six inches deep, which is rapidly cooled.

From the coolers the wort descends into what are termed the *fermenting backs*, a series of square vessels of enormous proportions, where it is exposed to the action of the yeast. The alcoholic fermentation here commences, with great energy, which ceases when the sugar of the sweet wort has been transformed into alcohol; and by subsequent distillation from the large copper *wash* stills, this alcohol is obtained in a more concentrated state, forming the *singlings*, or *low wines*, of the distiller.

The system of supervision whereby the revenue in spirits is collected, is rightly, as DODD states, a remarkable instance of Excise machinery—a supervision rendered important by the great revenue yearly collected, and by the comparatively small number of distilleries from which the payments are made. The Messrs. SMITH's establishment alone pays *three hundred thousand pounds* annually to Government on the spirit manufactured; and as the duty per gallon is estimated on spirit of one particular degree of strength, the greatest caution is necessary in testing all the liquors produced, as a guarantee that every sample is charged exactly in proportion to its quantity and to its strength. There are Excise officers, as agents for the Government, almost constantly present at every distillery, day and night. They succeed each other, one or more at a time, as may be necessary, after intervals of eight hours; the periods being from six in the morning till two, thence to ten at night, thence to six the following morning. The act of Parliament to regulate distilleries was passed in 1825, and by its provisions no distiller was permitted to work till he had procured a license, which was to be renewed yearly; moreover, he was not allowed to have on his premises a still below a certain capacity. The number of stills, charges, receivers, *et cetera,* continues subject to certain restrictions; and the exact routine is given as to the mode the liquid shall run from one vessel to another in the process of distillation. The openings in the principal vessels are expressly stated; and the most scrupulous care is taken that nothing shall pass from one vessel to another without traversing a pipe having a lock or valve, which is provided and kept in repair by the distiller, to the satisfaction of the Excise officer—who has charge of the key—under a penalty of two hundred pounds. This functionary also keeps the keys to lock up the furnace doors and stills; in fact, he exercises a perfect control over every operation and process; and with the view of facilitating his superintendence, the brewing and the distilling take place at different periods, one portion of time being set apart for the preparation of the *wash,* and another for its distillation.

In order that the intentions of the law may be fully carried out, prohibiting the synchronous brewing and distilling, the buildings are detached, or conveniently divided, and the pipes, a large number of which is visible, are of various colors. The legislature requires that the conduit pipes shall be painted *black;* those for the conveyance of wash, *red;* those for the first distillate, *blue;* and those for the finished spirit, *white:* this is done in order that the officer may conveniently trace the routine of the processes; further, ladders and all other conveniences must be furnished for the easy access of the supervisor to all the vessels in the establishment.

The new act specifies that no spirit receiver shall be used in any distillery, which shall not be made, placed, and fixed, to the satisfaction of the Commissioners of Inland Revenue, and be sufficiently deep to admit of the gage being taken of the depth of fifteen inches in the centre; and every such receiver shall be so filled, that at the time of gaging the same, for the purpose of charging the duty thereon, the depth of spirit shall not be less than fifteen inches, under a penalty of fifty pounds.

The fabrication of ardent spirits is a very extensive branch of home trade. Whisky is the staple produce in this kingdom; gin, rum, *et cetera,* are made in other countries by operations analogous to those followed in the manufacture of whisky. Gin and rum are fictitiously made by several parties in this country; but they require an alcoholic liquor to operate upon, and for this purpose whisky, more or less pure, is universally used. Since whisky, then, is the principal product of the spirit manufacture of this country, preference of description will be given to it.

For its production, barley is the most abundantly employed of all the cereals, and either in the raw or malted state. Malting is a preliminary operation to which the barley is submitted by those who employ malt; but since it is not *solely* used by the distiller, the detailed description of the operations of malting will be reserved to come under BEER, as only malt is employed to yield this beverage. To show, however, the influence the malting has on the workings of the distiller, it will be necessary to notice one particular change that takes place in the constituents of the grain, namely, the metamorphosis of starch and gluten into sugar and diastase.

The change of starch into sugar is partly effected in the grain during the time it is permitted to sprout, but principally after the amylaceous and glutinous matters, or diastase, have been extracted by the water, as the latter body possesses the property of readily transmuting the remainder of the starch into sugar. The conversion of the nutritive parts of the grain here alluded to, disintegrates its natural texture in such a manner, that water will readily permeate the entire substance, and take up every particle that is of any interest to the brewer or distiller. For this reason malted grain is preferred by many distillers: firstly, because the extract is obtained more perfectly and with greater facility; and secondly, because it is supposed that the yield of spirit is larger than would be produced were the grain unmalted. But, as additional labor always involves greater expense, the cost of the malted substance is necessarily higher; besides, a Government duty is imposed upon the article, which further raises its value. To avoid, then, the expenditure which the purchase of malt exclusively would occasion, many distillers use, instead of it, a mixture of malted with raw or unmalted grain, in various proportions; and though the subsequent extraction and management of the worts from such mixtures do not offer equal facilities as when malt has been employed, yet the inconveniences are, for the most part, overcome by care and foresight; and should any slight difficulty appear, the distiller consoles himself with the assurance, that the difference in the cost of the original material will fully compensate any of the minor casualties.

By guarding against the difficulties to be encountered, when a mixture of raw and malted grain is operated upon, as will be pointed out in the succeeding pages, the yield of spirit will be as large as if malt was wholly taken; a fact proved by CLEMENT and others who have investigated the subject, and also by several intelligent manufacturers.

Whether malt is exclusively used, or a mixture, the substance must be either ground or crushed, in order to destroy the adhesiveness of the valuable principle of the grain, and to expose an extensive surface to the solvent action of the water in the preparation of the extract. As said before, the malting effects the disintegration to a considerable extent; hence the reason why malt is not required to be in a very minute state of division when subjecting it to the action of solvents. On the contrary, mixtures, into the composition of which large quantities of raw grain enter, must be finely ground, for the cause just assigned.

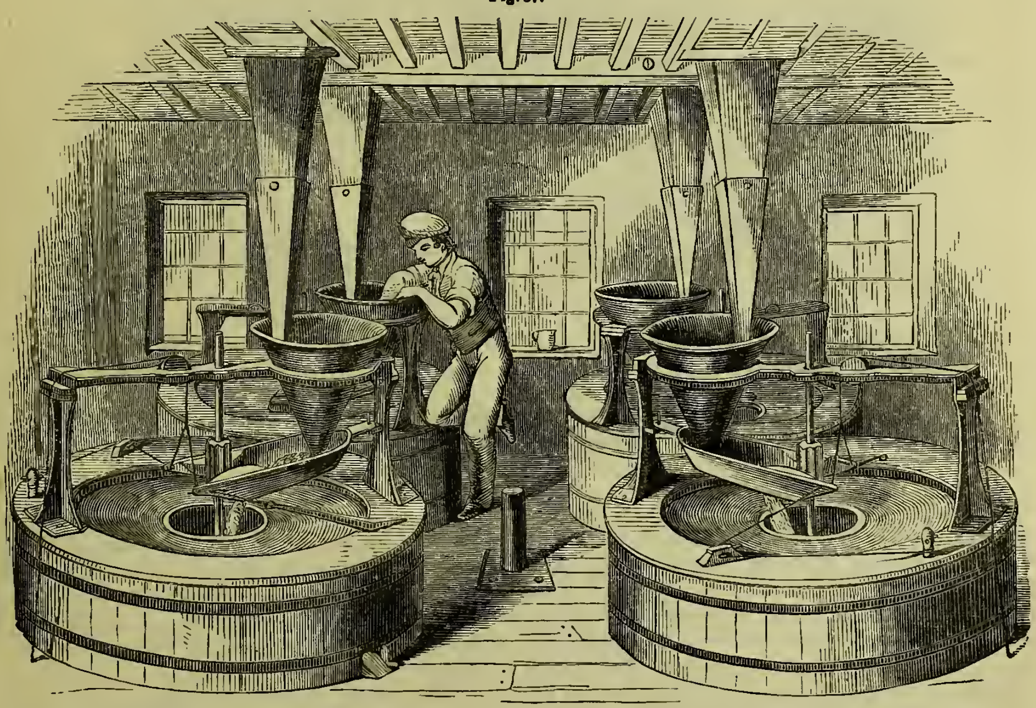
Ground or crushed malt always yields a wort that is comparatively clear; mixtures, on the other hand, never give a bright wort, but dense solutions, on account of the large quantities of starch and plastic matter which are carried off mechanically in the water.

This behavior of the malt and mixtures, constitutes one of the principal differences between the brewer's and distiller's mode of making the worts; the former must have a clear extract, as the liquid, after being submitted to the slow fermentation, remains to give *body* to his beverage. Such an extract cannot be otherwise obtained than by using malt entirely. It is optional with the distiller whether he uses malt or mixtures to prepare his worts, as he can run the starchy liquor into the fermenting tun, there to undergo the alcoholic fermentation, partly by catalysis, or the action of contact, and partly by the preliminary alteration of the starch, owing to the activity of the fermentation, into sugar before the alcohol is formed.

In other respects, the operations of the brewer and of the distiller are closely allied, excepting, that the distiller's object is to urge fermentation to its utmost, and finally, to separate by distillation the spirit thus formed from the wash, after which the residuary liquor is accounted of little value; but the brewer's aim is to prevent the fermentation going beyond a certain point, and the alcohol produced is left in conjunction with the wash.

Considerable attention is required of both parties, and especially of the distiller who employs raw grain, in preparing the worts, owing to the tendency of the matter *to set*, which prevents him from extracting the valuable portions. The main point, however, in the distiller's business, demanding particular care, is the proper management of the fermentative action succeeding the making of the worts, to insure the conversion of the whole of the saccharine matter into alcohol: he must also guard against the acetous fermentation, and various other difficulties, which, if overlooked, would be extremely detrimental.

Fig. 37.



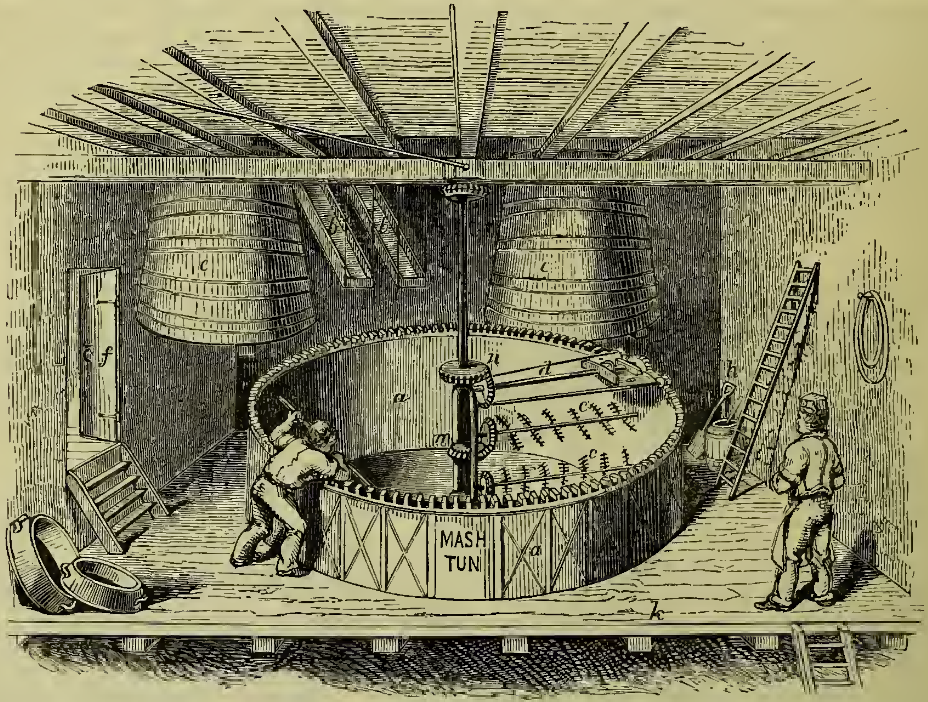
The several stages in the manufacture will now be fully treated of under the heads—GRINDING, MASHING, FERMENTING, and DISTILLING.

GRINDING.—The granary is a large building of brick or stone, having three spacious stories, on which the malt or raw grain is hoarded. One of the granary floors is appropriated to the kiln-dried barley, which lies spread in a stratum five feet thick, ready to be conveyed to the mill. When it is to be ground into meal, the grain is taken to a room immediately over the mill-chamber, and discharged through trap-doors into cloth sleeves, which conduct it to the hoppers. In the mill-room several pair of stones are seen ranged in a circle, and are set in motion by a shaft from the steam-engine. Fig. 37 shows the nature of the operations. These stones grind all the raw grain; while the malt is passed through a crushing-mill, consisting of two rollers placed nearly in contact. In the lower room is a vertical cylindrical partition, enclosing the mechanism whereby the millstones are rotated in the room above, and around it are pipes or openings for conducting the meal from the grinders into sacks fastened to them. The meal, as it issues from these pipes, has a temperature of about 100° Fahr., from the mechanical friction of the stones.

Mashing.—The mash tun is the most important vessel employed in this department. It is made of cast-iron plates, firmly bolted together, and circular in shape.

Fig. 38 represents the mash tun at a large Scotch distillery: *a a* is the mash tun, twenty-eight feet in diameter, and eight feet deep. From the middle of the tun rises a vertical shaft, *m*, set in motion by machinery, and thus revolving the mechanism, *d c c*. This apparatus, by rotating horizontally and vertically, effectually rummages the whole liquor in the tun: *d* is a rod extending from the pillar, *m*, to the edge of the tun, round which its outer extremity is carried on a toothed wheel, gearing into the teeth round the tun; it is driven by the bevel wheels, *n*. Connected with this rod, *d*, are two parallel rods, *c c*, which it carries round with it; to these rods are fixed bent cross bars or feathers, which also revolve in consequence of the double motion of the rods, *c c*, rotating on their axes at the same time that they turn round the shaft in the centre of the tun. In their action they much resemble the paddles of a steamer, mashing and churning the menstruum. The one rod is exactly over the other; the paddles attached to the lowest, pass within two inches of the bottom. When the tun is only half filled, the lower rod, *per se*, mashes the contents. *k* is a platform, so that the men may have easy access to the tun; *f* is a door leading to the mill, where the grain is ground into grist; *b b*, two channels or sluices, for conducting the grist from the granary into the mash tun; *e e*, wash-backs, resting on rafters, *et cetera*, which project from the wall. The wash-backs are used for containing the weak worts drawn from the last two *sperges*, or mashings of the grist, after the principal extracts have been drawn off; they are pumped up into *e e*, and kept to macerate fresh grist in the next operation; *h*, the entrance to the long rooms, in which are twenty or thirty fermenting tuns. Several large copper vessels, besides the tuns, are in use, for the purpose of heating the water for mashing the grist; they hold several thousand gallons, and are heated by a furnace.

Fig. 38.



Having described the mash tun, the operations and materials employed for the preparation of the worts will be now considered.

It has already been stated that the grist may be barley meal, oats, or malt in variable proportions, according to circumstances. Large quantities of oats, on being mixed with the grist, confer a peculiar flavor, which is easily recognized by those who have experience in the taste of spirit. When barley malt and raw barley meal form the grist, one part of malt to two or three parts of the raw ground grain are considered the best proportions, though one part of malt to five, six, eight, nine, or even fifteen parts of the raw grain are often used. When oats are employed, the best proportion is three parts of barley malt to one of oats; but satisfactory results are obtained when the malt and oats are used in the ratio of two of the former to one of the latter. If the proportion of raw grain be large when compared with that of the malt, it is a general custom to add a quantity of chaff, in order that, when the mashing water has extracted the saccharine and starchy portions, it may be more easily filtered or drawn off.

The quantity of malt and grain used at each mashing, depends on the size of the distillery; hence no fixed rule can be laid down. In the distilleries in Dublin, the quantity of grist at each brewing varies with circumstances, from eight hundred bushels, the lowest, to two thousand bushels, the largest quantity. In nearly all cases, it is composed of seven eighth-parts of raw or unmalted, and one eighth-part of malted grain.

Previous to introducing the malt, a quantity of water, at a temperature between 140° and 150° Fahr., is run into the mash tun, and the ground malt and meal are then added. A number of workmen, with stout wooden spatulas or oars, keeps the mixture in brisk agitation, until the grist is thoroughly moistened, and neither clots nor lumps remain. In the larger establishments, this part of the operation is effected by machinery, and is much more efficiently performed than by manual labor. The perforated false bottom allows the wort to percolate into the space between it and the true bottom of the tun, from which it is drawn off more easily into the under-backs,—large vessels placed beneath the mash tun, wherein the worts are collected till pumped into the cooling-backs. Distillers and brewers are more variable in their mode of working than any class of manufacturers who carry on business extensively. In no one operation do they seemingly follow a common rule, each having some favorite plan of a supposed greater merit than others; hence the difficulty of giving a true and comprehensive detail of these branches. This assertion has been partly demonstrated already, when speaking of the grist; and in the next operation, the mashing, it becomes more manifest.

The whole of the saccharine and fermentable matters of the grist introduced into the mash tun, is generally extracted in three, always in four mashings at most; but the manner of doing so is different, according to the notions of the manager. At one time, the first, second, and third mashings were evaporated till the mixture acquired a density of about 1·05, when it was ready for the fermenting tun, the fourth wash being reserved for extracting fresh quantities of grist. Some employ the water in the first and second extract in such quantities as that the wort will be of a strength fit for fermenting, and the third and fourth wash may be concentrated by evaporation to the proper density, and then added to the preceding; or these dilute solutions may be made of the proper strength by running them on fresh quantities of ground malt and grain. Others, again, manage the quantity of water in such a manner that the product of the first extract will have the density necessary for submitting it to the fermenting vessels. The remaining three washings are rendered stronger either by evaporation, or mashing with fresh portions of malt or grist. In the latter case, the quantity of water is larger in the first mashing than in the preceding instance, where the first two extracts are made of the strength 1·050, which together amount to about twice the volume of grist

In **Macfarlane** and Co.'s distillery at Glasgow, two hundred and sixty hundred-weight of grist, including a sixth or a fourth of malt, are taken for an ordinary mash, and these are put into the mash tun, and about seven hundred and eighty-eight barrels of water—nearly twenty-eight thousand three hundred and sixty-eight gallons—are poured upon them at two stages of the operation.

In the Dublin distilleries, about seven-eighths of raw grain are employed. Like the preceding, the first mash is the only one let into the fermenting tun, the succeeding small worts being kept for the next day's brewing; and in preparing this wort about five barrels of water are taken to the quarter of grist, but more if small worts are used; to completely exhaust the grist, about the same amount of water is required for the subsequent mashing.

The temperature of the water varies with the quantity of malt present; when the malt and raw grain are mixed in the proportion of one of malt to two of grain, the first mashing may be made at a temperature of 150° to 160° Fahr., but if the malt and grain be as one to four, six, or nine, then the water should not exceed 145° for the first mashing, in order to prevent the *setting* of the mass. A longer time is likewise required for the first mashing with a large quantity of raw grain than if it were entirely malt, as the starchy matter of the grain is more difficultly extracted than the saccharine principle which replaces it in the malted grain. From one hour and a half to two hours generally suffice for this operation, where the contents of the mash tub are kept in agitation by machinery, and the proper heat of the water has been attended to; but very often the time occupied may extend to three or more hours.

In successful cases, the time required for the wort to clarify, is about one to two hours. As the temperature of the solution becomes lower from contact with the grist, and from the agitation, it is customary not to add the whole of the water employed in the first mash at once, but to retain from half to a quarter of the liquid, which is added, at short intervals, towards the middle of the operation. This serves to keep the heat more uniform, and the work is more effectually accomplished.

In the Scotch distillery above mentioned, when the first water at 140° permeates the whole of the grist, the remainder of the seven hundred and eighty-eight barrels is poured in, at a temperature ranging between 175° and 180°, so as to heat the whole contents of the tun to 150°.

After the wort has been drawn off into the under-back, and pumped into the coolers, the second *sperge* is then let in upon the grist remaining in the mash tun, and a similar treatment to the foregoing given to the mash; the time occupied is one hour and a half, and the density of the weak wort is from fifteen to sixteen pounds per barrel.

Since the greater part of the saccharine and starchy matters of the grist is extracted in the first affusion, there is but little danger of the setting of the mash in the second washing, so the water is of a higher temperature than that employed in the first case, generally 180° Fahr.

After this wort has been let into the under-back, the third and last sperge is made, and in about an hour and a half the wort is drawn off; its density is from three to five pounds per barrel. Both these mashings are pumped into wash-backs, and are let down to form the first mashings in the next day's brewing, and thus the work succeeds by *three* sperges or waterings of the grist; the first being drawn off at the proper density for fermentation, while the remaining two are retained to be further strengthened by additional extractive matter.

On tasting the solution during the *infusion* of the first wort, a very peculiar difference is observed. At first nothing particularly striking is apparent, but in a very short time the solution begins to acquire a sweetish taste, which becomes more perceptible till in the end the liquor possesses the lusciousness of malt worts. Hence it is evident, that the starchy matter of the grist, as it is extracted, is resolved into glucose, or grape sugar. Two causes serve to effect this change: the first and chief agent is the peculiar body *diastase*, which is generated in the malt during the germination of the grain. This body possesses the property of converting much more starchy matter into sugar than is present in the malt. It reacts on the starch of the raw grain, and produces the same action as if the grain itself was malted. The gluten of the grain is capable of producing the same change, but it requires a considerably longer time than the active body in malt. When only one part of malted barley is used to five of the ground raw grain, the excess of the vegetal principle, diastase, is sufficient to effect the ready transformation; but when nine parts of the raw material are used to one of malt, the quantity of the active principle in the malt is inadequate to saccharify the whole of the starch, and a portion is consequently left to the slower action of the gluten: this accounts for the longer time and greater trouble which the wort takes in preparing for the still when a large quantity of the raw grain is proportioned to the malt. When a wort is being made, considerable time elapses before the starch is wholly transformed into sugar, and in the ordinary period allowed by the distillers in the fabrication of the worts, this conversion is never complete, a large portion of starchy matter remaining unaffected. Thus, if it be attempted to make a wort of two hundred pounds of saccharine matter per barrel in the ordinary way, the process fails, in consequence of the starchy matters assuming a jelly-like appearance long before the above strength is attained. In order to obtain the strongest wort possible from raw grain, the extract, diluted, should be left to repose for a longer period, during which the gluten reacts like the diastase of the malted grain, and when the whole of the starchy matter becomes soluble, the solution is drawn off and concentrated by evaporation at a low temperature.

The specific gravity of the first wash is generally about 1·050; the second wash has a specific gravity of about 1·010 to 1·015; the third, 1·008; and the fourth is little higher than water. The strongest wort procurable from grist, containing over four parts of unmalted grain, is obtained by evaporating the first mashing. The strength, even by this treatment, never exceeds one hundred and fifty pounds of saccharine matter per barrel, while the wort of malt, treated similarly, may be obtained of two hundred pounds to the barrel.

In consequence of restrictions once imposed upon the distiller by the Excise, he was precluded from attempting to manage the worts by any decided improvement in method or principle, and had to submit to the dictates of a Board, whose judgment in such matters was often inferior to his own. When these regulations were first drawn up, the Scotch distillers were compelled to produce, from one hundred gallons of wort, nineteen gallons of spirits, of one-to-ten over hydrometer proof, or of a specific gravity equal to 0·90917. At a later period, the quantity of spirits was reduced to fourteen gallons, and, still later, to thirteen gallons, from the hundred gallons of wort. The strength of the wort was regulated at this period, and specified at seventy pounds of saccharine matter per barrel. The English distillers were exempted from these changes in the regulations, so that they continued, as usual, to make their worts of whatever strength they thought proper to yield the nineteen gallons of one-to-ten over proof.

On the supposition that the whole weight indicated by the saccharometer had been decomposable matter, capable of yielding alcohol in the fermenting tun, thirteen gallons of the forementioned strength would be produced according to theoretical calculations; but this is never obtained in practice, for, from repeated experiments, conducted on a large scale with every requisite care, it has been found that not less than fifteen pounds of saccharine matter remain undecomposed, so that only fifty-five pounds of the seventy prescribed by the Excise regulation came into active operation. When the quantity of spirits was nineteen gallons to the hundred gallons of wort, it was made of the requisite strength by producing a concentrated extract of saccharine matter from malt, raw grain, *et cetera*, and adding it to the wort till the proper density was obtained.

From the supposition that this infusion was made up of sugar, treacle, and other similar articles, the parliament prohibited its addition to the wort in the Scotch distilleries; and its strength was limited to seventy pounds of saccharine matter per barrel, in order to prevent the secreting of the excess of spirits which a strong wort would yield above the standard quantity—thirteen gallons.

It has been said that a wort of sixty-two pounds per barrel, which would yield twelve per cent. of spirit of one-to-ten strength, or 0·90917 spec. grav., is preferable to the proportion adopted by the Excise. The original Dutch hollands are obtained from a wort considerably weaker than the above, and it is generally admitted that the Dutch spirits are superior to the Scotch.

The whisky made by smugglers in Scotland was long preferred by the inhabitants, and was purchased at a higher price, under the name of Highland whisky. This was partly owing to its being made entirely from malt; but the chief reason was, that, from the unfavorable circumstances under which they operated, their wort was necessarily much weaker than the wort of the legal distillers, and, on an average, was not much stronger, probably, than the wort of the Dutch hollands.

For a long period, the illicit production of spirits in the highlands of Scotland was a great source of annoyance to the Excise, and of trouble to the parties illegally distilling, to such an extent that several of them had been ruined thereby. The public, too, helped to maintain this contraband trade, for the smuggled goods were, generally, preferred to those of the legal distiller, on account of the improved taste and bouquet which the former were supposed to possess. While this feeling remained, it was impossible to put an end to the production of smuggled whisky in Scotland. To overcome the preference of the inhabitants for the highland spirit, Government removed the restrictions which bound the manufacturers, so far, that they were able to distil from malt at almost the same rate as they before did from grain. Hence the high reputation of smuggled whisky has gradually fallen off, and the business of those engaged in it has almost discontinued.

The chief reason, it is asserted, that influenced the Government to retain the limitation under which the distillers were placed, was to insure the payment of the duty on the spirit actually distilled; yet it was a matter which required elucidation, how the duty could be levied with greater accuracy though all the restrictions on the strength of the wort were removed. Experiments have pointed out, that in the best-conducted distilleries not more than four-fifths of the saccharine extract in the wort undergo the alcoholic fermentation, and that, for every pound of such extract that suffers decomposition by the fermentative process, half a pound of alcohol, spec. grav. 0·825, is produced; since a gallon of the spirits, one-to-ten over proof, or spec. grav. 0·90917, contains four and three-fifth pounds of alcohol of spec. grav. 0·825, from which it is evident, that for the production of a gallon of spirits of 0.90917, the decomposition of nine and one-fifth pounds of sugar are required; but as only four-fifths of the quantity of sugar present suffers the alcoholic fermentation, eleven and a half pounds will be required in the wort for production of the above quantity of spirits. The regulation of the Excise laws might be based upon these facts, and the duty levied on the wort proportionably to the quantity of saccharine matter, allowing eleven and a half pounds for every gallon of spirits.

At present the distiller can bring his wort to any degree of strength he may think proper or advantageous; but he must give a written notice of this to the Excise officer in attendance four hours before running the wort into the fermenting tun, or he will incur a penalty. The duty imposed is regulated by the strength of the worts, and the subsequent gravities and measurements which are repeatedly taken.

In the employment of malt, the proportion, in moderate-sized factories, stated by URE, is five hundred bushels, coarsely ground. This quantity is introduced into the mash tun, which is of a size proportionate to this supply of malt, and nine thousand gallons of water, at a temperature of 160° Fahr., are run in upon it. The whole is kept in brisk agitation, by machinery, for an hour, then allowed to rest, and, after the grains have subsided, about six thousand gallons of wort are drawn off into the coolers. From four thousand five hundred to five thousand gallons of water, at 180° Fahr., are run in upon the residuary grains in the tun, and the mashing continued for about three quarters of an hour; the mixture is then allowed to rest, and the weak worts drawn off. A third treatment of the grain, with the same amount of water as the preceding, takes place, in order to take up all the soluble matters of the grain; and when this has been drawn off, and the grains have been drained of all the solution, both the second and third mashings are mixed, which constitute nine thousand gallons; the mixture is employed next day, at a temperature of 160°, to mash five hundred bushels of fresh malt, and is drawn off into the coolers, when it has become saturated with saccharine matter, as before shown, and the residuary grain subjected to the same operation as the grains of the preceding day.

Sometimes rye is used instead of malt. Ninety bushels of it are mixed with one hundred and ninety bushels of raw grain, thus constituting two hundred and eighty bushels in the whole, for the mashing of which five thousand two hundred gallons of water are required. The temperature of this water, as is pointed out in the beginning of the remarks on this part of the subject, should not be so high as when all malt has been used, and as was also stated above, the time allowed for mashing is greater; the subsequent washings are reserved for exhausting fresh portions of grist.

THE COOLING.—Wort of grain has a much greater tendency to form acetic and saccharic acids than the malt worts. Saccharic acid contains the same number of equivalents of carbon as sugar, and seems to be produced from sugar in the same way that the acetic acid is from alcohol.

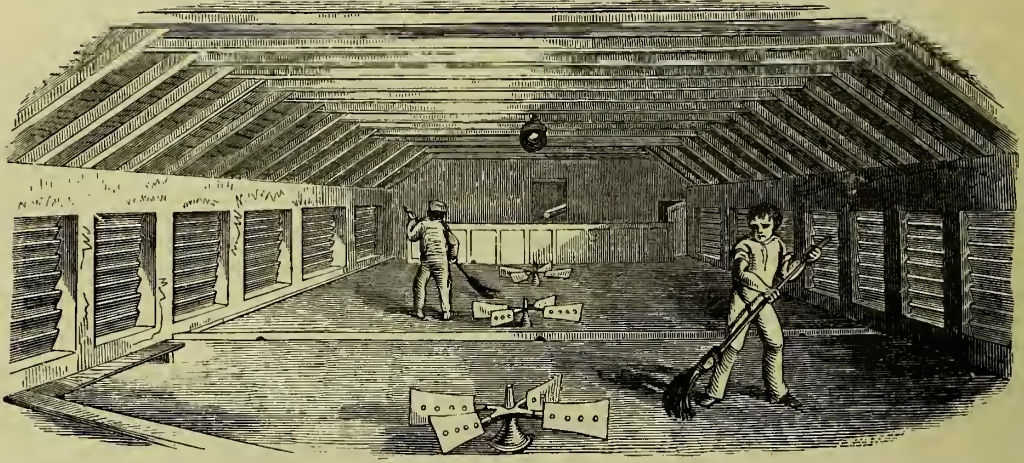
Seven atoms of anhydrous sugar contain the elements of one equivalent of saccharic acid, three equivalents of melassic acid, and seventeen equivalents of water; and this is at once shown by the annexed formulæ:—

$$\begin{array}{c} \text{Seven equivalents of sugar,} \\ \text{equal } C_{84}\,H_{63}\,O_{63}. \end{array} \left\{ \begin{array}{rlr} 1 & \text{Saccharic acid,}\,.\,. & C_{12}\,H_{10}\,O_{16} \\ 3 & \text{Melassic acid,}\,.\,. & C_{72}\,H_{36}\,O_{30} \\ 17 & \text{Water,}\,\ldots\ldots\ldots & H_{17}\,O_{17} \\ \hline & & C_{84}\,H_{63}\,O_{63} \end{array} \right.$$

On account of the liability to acetification above alluded to, it becomes the important business of the distiller to oppose it, which is done by bringing the solution as speedily as possible to that temperature at which the fermentation proceeds. Various methods are pursued by different distillers, according to the extent of the factory.

In several of the factories the coolers are shallow rectangular vessels, into which the first wort is pumped as soon as it has passed the under-back, to the depth of two, three, four, or more inches. The coolers in Messrs. MACFARLANE'S distillery are two in number, each being one hundred and twenty-four feet in length, by thirty-two in breadth, and nearly a foot deep. Fig. 39 represents one of these coolers. They are placed at the upper part of the building, one over the other, and are open on all sides to the winds. Over each cooler is fixed three *flighters*, or machines like horizontal windmills, which, as they are made to revolve rapidly by means of an engine, sweep a powerful air-current over the worts, producing also a circular current in the liquid, which makes it traverse the coolers equally. As the wort is introduced into these coolers, it stands at 135° to 140° Fahr., and is cooled here to 70° or 80°, the temperature at which it stands when run into the fermenting tuns; this cooling is effected in about five hours in the winter-time, but requires eight or nine hours in the summer season.

Fig. 29



An improved method of cooling the wort has lately been followed, *videlicet*, by conveying the hot liquid through a course of tin piping placed in a stream of cold water. By this means, and the use of the proper extent of piping, the wort may be cooled down to the temperature of the surrounding water, or any other intermediate degree that may prove most advantageous. Worts cooled down by this means lose none of the water by evaporation, as they otherwise would do if cooled in the flat shallow wooden coolers, and consequently, with the exception of the little alteration in gravity the difference of temperature occasions, the worts remain of the same density that they indicated when drawn from the under-back.

FERMENTATION is the most important stage through which the materials in the hands of the distiller have to pass, and one which not only demands considerable skill and attention for its proper management, but also requires extensive knowledge, both of the principles of chemistry, and of practical results. Indeed, the success of the operation almost entirely depends on the fermentation of the wort; and, unless governed with due care and dexterity, a failure will be the consequence. If the distiller possesses superior knowledge, and is acquainted with scientific data, a favorable field for practice is offered to him, to bring those acquirements to bear upon this part of his business. The proper fermentation of worts oftentimes baffles the most skilful, the process being so changeable in its nature. Formerly, the Scotch distillers used to add three and a half per cent. of fresh yeast, or four to four and a half, and sometimes five per cent. by measure of stale yeast, to the wort in the fermenting tun. The whole of the yeast was not added at once, but in two, three, four, or more quantities. Usually one and a quarter to one and a half per cent. of yeast was added the first day, and the remainder on the second and third days; though some managed by introducing the whole of the remaining yeast, after the first addition, on the third day, and, if requisite, a further quantity to complete the fermentation. Fresh yeast, if it could be obtained, was taken at first, and the succeeding quantity put in might be stale yeast; in which case a larger measure was employed than if the ferment were fresh.

The large amount of yeast formerly employed was in consequence of the great density of the worts. Distillers now generally use from one to one and a half per cent. of fresh yeast, very rarely two per cent. Of this about three-fourths per cent. are added when the wort is let into the tun, and the remainder after the second day—sometimes when the attenuation reaches 1·030 or 1·035. The quantity subsequently added may be stale yeast, taking, however, a little excess over the usual allowance of the fresh ferment.

This yeast is invariably obtained from the large London porter breweries, the quantity produced in the provincial ones being insufficient. The portion of yeast which is thrown off the porter during its fermentation, is the best; but often that sold is the slimy dregs which remain in the bottom of casks when the clear porter is racked off. A great deal of the success of the fermentation depends upon the goodness of the yeast, and the quantity used is regulated by its freshness.

In the course of fermentation, the liquid incalesces about 20° Fahr. above its ordinary temperature. DONOVAN gives the following as a fair statement of the specific gravity and temperature of the wort of a five days' fermentation, the original specific gravity being 1·050:—

	temp.	spec. grav. of wort
First morning,	70°	1·050
" evening,	70°	1·050
Second morning,	72°	1·046
" evening,	76°	1·032
Third morning,	80°	1·022
" evening,	84°	1·012
Fourth morning,	88°	1·007
" evening,	88°	1·005
Fifth morning,	88°	1·003
" evening,	86°	1·001

The time occupied by the fermentation varies, extending over a period of between three and six days, and, on some occasions, seven or nine days. Difference of season has a great influence on the celerity or slowness of the fermentation. During the first few days the tuns are exposed as much as possible to the atmosphere, and after this time they are covered over tightly to exclude the air. Two reasons have been alleged for this arrangement: first, to prevent the escape of the carbonic acid, which, it is supposed, forwards the action; and, secondly, if suffered to diffuse itself into the atmosphere, it would carry off portions of the alcohol. For the first supposition, some explanation may be offered. It seems that the carbonic acid, when confined, causes the greater attenuation of the liquid. It is known that the carbonic acid from fermenting tuns, when conducted through fresh worts, causes fermentation; but this is not so complete as when yeast is added. It may, however, happen, that a portion of the active principle of the ferment is carried over mechanically, and that by this the fermentation is caused, it being doubtful whether carbonic acid generated from any other source would have the same effect. With regard to the second reason, it is scarcely admissible, as the fermentation is nearly terminated before shutting down the tuns.

Distillers never take yeast from the fermenting tuns, but beat it into the liquid, being of opinion that any such abstraction would render the fermentation less complete, and consequently diminish the proportion of spirit.

The best temperature for the wort, when let into the fermenting tuns, is about 70° to 75° Fahr. in winter, but often it stands about 57°; during the fermentation the temperature rises 20° or 25° Fahr., being at the maximum elevation between 82° and 90°. When the heat of the liquid, at the commencement of the fermentation, is about 70°, the acquired caloric will be apt to raise the liquid to a degree which is favorable to its acetification; hence great care must be exercised to prevent the temperature exceeding 95°.

Difference in the time of the fermentation of worts is nearly always observed, owing to the variation of the quality of the yeast. As the fermentation proceeds, the specific gravity of the wort diminishes, in consequence of the decomposition of the saccharine matter into carbonic acid and alcohol, which is expressed by the distillers as *attenuation*, and is the standard by which they judge of the success of the operation. The amount of spirit which the wash or wort will yield, may be known from the determination of the specific gravity, or degree of attenuation, which has taken place.

Two reasons may be offered for the diminished specific gravity after fermentation.

1. The disappearance of the saccharine matter in the fluid, which, were it not for other fixed bodies present, would lower the density to that of distilled water. The whole of the sugar, however, is not decomposed, and, consequently, the specific gravity of the fermented wort, apart from the consideration of the alcohol generated, would be proportionally greater than the water in its ordinary state, as the quantity of undecomposed matter is more or less.

2. The results of the fermentation are carbonic acid, which escapes, and alcohol, which remains; the alcohol, having a less specific gravity than water, diminishes the density of the latter. The aim of the distiller is to have the attenuation of the wort to correspond with water, which may be readily done, provided his yeast is tolerably good, and that his worts are dilute. When this object is gained, it does not, however, follow, as many of them suppose, that the whole of the saccharine matter has been decomposed. The weight of a volume of alcohol being much less than that of a corresponding volume of water, it is evident, if both be comminuted, that the resulting liquid will have a specific gravity less than the latter; and to make up the strength, so as to equal the density of water, a greater or less amount of saccharine matter is requisite, or, in other words, a quantity of saccharine matter remains undecomposed, which raises the density considerably higher than that of water at ordinary temperatures. Generally, this quantity of undecomposed sugar increases with the original strength of the worts, as the alcohol generated in the proportionate bulk of those extracts is larger; and with it the decomposition of the saccharine matter is partially arrested, in consequence of the property which alcohol has of preventing eremacausis, or fermentation. This fact is easily proved by adding some alcohol to a portion of the wort in active fermentation, so that the liquid will indicate a specific gravity equal to, or a little below water; the action of the ferment is arrested, and the sugar, necessarily, remains in the liquid intact. If the solution be introduced into a retort, or small common copper still, and about one-third of the liquid drawn off at the temperature of the water-bath, the spent wash in the still run once more into a vessel, and a little yeast added, active decomposition of the sugar sets in, and a corresponding quantity of alcohol and carbonic acid is produced. The case is similar in the fermentation on a large scale: and the annexed table, which is taken from the Encyclopedia Britannica, shows this in a clear manner. The density of the nine worts examined ranged about 1·045, and the degrees of attenuation to which they were reduced were as follows:—

1.	Specific gravity after attenuation......	1·0012
2.	" "	1·0045
3.	" "	1·0018
4.	" "	1·0000
5.	" "	1·0012
6.	" "	1·0045
7.	" "	1·0047
8.	" "	1·0007
9.	" "	1·0007

Upon examining the wash after the termination of the fermenting action, it was found that 4·34 parts of the sugar had been decomposed, and that one part remained intact; thus showing, that when worts are even purposely diluted, nearly a fifth part of the saccharine matter will escape decomposition; and, where worts are much stronger, or more concentrated, of course the loss will be much greater. On the large scale, the attenuation cannot often be carried below 1·0012. Some rare instances may occur, in which the specific gravity may be reduced to 1·000, or even 0·998; but in these instances, the worts must be in a proper state of dilution, and the ferment, or yeast, of the first quality.

URE mentions the works of a Scotch distiller, where the wash, when let into the tun, had a specific gravity of 1·065 to 1·060. The contents of the fermenting tun are stated at three thousand gallons of wash, and the temperature, at the time of its introduction, 64° to 74° Fahr. Two gallons per cent. of barm were added, and the liquid agitated. When the attenuation had reached 1·04, another gallon per cent. of barm was added. He further remarks, that if the fermenting tuns are small, the temperature of the worts should be higher than when the reverse is the case. Fermentation is known to proceed favorably when the bubbles of carbonic acid mount in rapid succession. Should the fermentation flag, it is almost a hopeless task to restore vigorous action. Some try the addition of *bubs*—wort brought into a rapid state of fermentation in a tub by a large proportion of yeast—but this plan is seldom successful; besides, the law prohibits the addition of any wort after the expiration of twenty-four hours from the time the fermenting tun is charged, and if it be known that after that time any has been added, the distiller incurs a penalty.

With concentrated worts the fermentation goes on briskly for a short time, and then, after the alcohol has accumulated, the fermentation lags, and no further addition of yeast will revive it. DONOVAN found that the saccharine matter in such fermented worts possessed a highly disagreeable taste and smell. Hence the necessity of having the worts properly diluted, to avoid too great a waste of saccharine matter; yet the worts must not be too dilute, for then the fermentation will sooner cease, and the diluted alcohol will be more apt to run into the acetous fermentation. The attenuation is urged no longer than the time that the head of yeast falls, the distiller thinking it more advantageous to overlook the matter remaining undecomposed, than risk the loss which he would expose himself to from the formation of vinegar. Indeed, unless immediate distillation of the fermented wort is resorted to, a heavy loss is often incurred from this source, and more so if the alcoholic liquor be exposed to the air for any considerable time. This is noticed by the increasing specific gravity of the worts, and the peculiar aroma of acetic acid. It is, however, easily guarded against; generally, distillation is resorted to; but if atmospheric air be excluded from the fermented liquor, no injury is sustained. For this purpose the tuns are rendered air-tight by means of a well-fitting cover, through which a large tube passes, and enters the bottom of an open tub placed over the fermenting tun, which, in this instance, is filled quite full; the barm and froth rising are forced through the pipe into the open tub, and when the fermentation slackens, these matters return into the tun. Many distillers use butter to keep the wash from overflowing the tun. In general, the fermenting tuns are conical vessels of larger capacity than is required to hold the wash when first introduced, which serves the double purpose of containing the froth, and preventing the escape of the heat generated during the process.

At present, in the larger distilleries, the fermenting tuns are of iron, and have an outer casing of wood. These are found to be much more easily managed than the wooden ones, the iron having a greater conducting power. Should the heat of the wort get too high, cold water is introduced into the space between the envelope and tun; and if it be too cold, it is readily brought to the proper temperature by supplying hot water.

As a good attenuation is the great desideratum, to the attainment of which the distiller's attention is particularly directed, it may be advisable, before closing this part of the subject, to enter more fully into its nature, and inquire into the causes which affect it, alluding, at the same time, to the alcoholic fermentation.

Fermentation may be regarded as the putrefaction of a substance void of nitrogen. A change of properties is produced in the substances fermented, arising from new combinations of their principles. Sugar, for example, is converted into alcohol and carbonic acid, by the process of alcoholic or vinous fermentation. This process, viewed under its simplest conditions, consists in adding a certain quantity of yeast, or other ferment, to an aqueous solution of sugar. Carbonic acid shortly begins to be eliminated, and the alcohol, simultaneously produced, unites with the water.

In addition to the alcohol and carbonic acid formed by the decomposition of the juice, there is also produced a yellow or grey insoluble substance, containing a large quantity of nitrogen. It is this body which possesses the power of inducing fermentation in a new solution of sugar, and which has, in consequence, received the name of ferment.

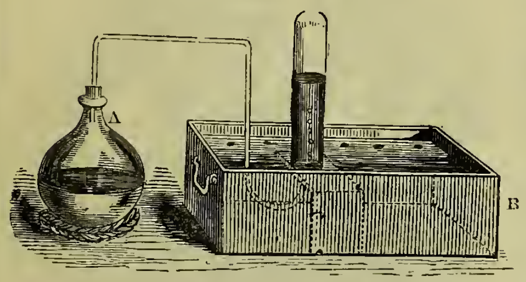
Yeast from beer, and that from wine, examined under the microscope, present the same form and general appearance. They are both acted on in the same manner by alkalies and by acids, and possess the power of inducing fermentation anew in a solution of sugar: in short, they are considered identical. The alcohol and carbonic acid are produced from the elements of the sugar, and the ferment from those nitrogenized constituents of the juice, termed gluten, or vegetal albumen.

The fermentation of pure sugar in contact with yeast, is evidently a very different process from the fermentation of wort, or of *must*—the liquid expressed from grapes when fully ripe.

In the former case, the yeast disappears during the decomposition of sugar; but in the latter, a transformation of gluten is effected simultaneously, by which ferment is generated. Thus yeast is destroyed in the one case, but is formed in the other.

The experiment may be most conveniently exhibited and conducted upon a small scale in an apparatus like the annexed—Fig. 40. The syrup and yeast are introduced into the bottle, A, from which a bent tube issues, passing under the inverted jar placed in the water-trough, B. It will now be found, that all that is requisite to induce fermentation, and the consequent production of alcohol from the above materials, is to subject them to a due temperature—say between 70° and 80°; they then soon begin to act upon each other, and the principal points to be noticed are—

Fig. 40.



Firstly, that carbonic acid is evolved;
Secondly, that the sugar slowly disappears;
Thirdly, that alcohol is gradually formed.

It will be further observed, that the contact of air, or oxygen, is unnecessary. It is, indeed, in many instances injurious.

As respects the quantitative results of this experiment, it has been ascertained by DUBRUNFAUT, BOULLAY, and DUMAS, that by commencing with cane sugar, it is, in the first instance, converted into glucose, or grape sugar, and that the grape sugar is then resolved into carbonic acid and alcohol.

Now, grape sugar, which, in its ordinary hydrated or crystalline state, is $C_{12}\,H_{14}\,O_{14}$, loses, when carefully dried at a little above 212°, two atoms of water, and becomes $C_{12}\,H_{12}\,O_{12}$; and assuming such to be its composition, one atom of the anhydrous grape sugar would be resolved exactly into four atoms of carbonic acid and two atoms of alcohol; or, in other words, one hundred and eighty parts of the dry grape sugar would yield eighty-eight parts of carbonic acid, and ninety-two of alcohol; the results of experiment confirm this theoretical deduction:

$$\begin{array}{l}1 \text{ atom of dry grape} \\ \text{sugar, } C_{12}\,H_{12}\,O_{12} =\end{array} \left\{ \begin{array}{ll} 4 \text{ atoms of carbonic acid, } & C_4 \qquad O_8 \\ 2 \text{ atoms of alcohol,\ldots\ldots} & C_8\;H_{12}\;O_4 \\ \hline 1 \text{ atom of sugar,\ldots\ldots\ldots} & C_{12}\,H_{12}\,O_{12} \end{array}\right.$$

If the starting point be cane sugar $C_{12}\,H_{11}\,O_{11}$, it yields somewhat more than its weight of carbonic acid and alcohol, inasmuch as it, in the first instance, assumes an atom of water to form grape sugar; but if, on the other hand, common grape sugar $C_{12}\,H_{14}\,O_{14}$ be taken, it affords less than its weight of carbonic acid and alcohol, because it contains two atoms of water in excess. Hence it is seen that one hundred and seventy-one parts of cane sugar, produce one hundred and eighty parts of carbonic acid and alcohol, while one hundred and ninety-eight parts of common grape sugar give the same results. It is also found that a very small quantity of yeast is required to excite the fermentation of grape sugar or glucose, whereas cane sugar requires a much larger proportion.

In the production of beer and wine, and in the case of the fermentation of a solution of sugar, as just described, the results, as relate to the production of alcohol, are the same; the sugar is decomposed in consequence of the presence of a ferment. When yeast is used, its particles are seen to become covered with small bubbles of carbonic acid, which cause them to rise to the surface of the liquor, where they discharge them, and as they again sink, they gradually acquire a fresh coating of bubbles, which they carry up as before; in this way, that intestine motion of the whole menstruum is produced, so characteristic of active fermentation. The process is also attended by a considerable elevation of temperature, and when complete, the liquor clarifies, the yeast precipitates, the sugar has disappeared, and in its stead is found alcohol. A trace of ammonia also makes its appearance.

These extraordinary changes can only be induced by the action of yeast, or some analogous ferment. Its *modus operandi* has been the subject of much experiment and discussion, and involves some very curious considerations.

MITSCHERLICH has proved that actual contact of the particles of the yeast with the dissolved sugar is essential. He suspended a wide glass tube, the bottom of which was made of bibulous paper, in a jar of a solution of sugar, the tube being itself filled with the same solution. Some yeast was then put into the syrup contained in the tube, where it soon induced fermentation, and the alcohol there formed passed through the pervious bottom, and, together with carbonic acid, diffused itself in the surrounding liquor; but the real phenomena of fermentation, namely, the destruction of the sugar and the formation of alcohol and of carbonic acid, were limited to the syrup in the tube containing the ferment, and the sugar in the outer vessel remained unchanged. Yeast which has been deprived of all matter soluble in water, still retains its power of exciting fermentation. The active part of yeast, or barm, is composed of minute vesicles, containing globules, and these germinate in the saccharine liquor, and produce a microscopic plant.

Few productions have created more interest, or excited greater discussion among chemical philosophers, than yeast, and its nature and mode of operation have been the source of many an anxious and keen inquiry. These points are now, however, to a very great extent set at rest; its fungoid character is generally admitted, and its action in inducing fermentation pretty well understood.

In one part, however, the history of the yeast plant is still incomplete, and this relates to its development. Most observers admit that the yeast fungus, in the different forms of yeast in use, is in an incomplete state of development, and many, influenced by this conviction, have made attempts to discover the plant in its perfect condition. Such was the motive which induced TURPIN, in the ardour of scientific zeal, to spend a whole night in a brewery, in order to trace out the successive steps in the germination of the yeast plant; and although he has stated that he made out distinctly that the cells of sporules became multiplied by budding, and that they adhered in couples, and even in rows, according to the time which had elapsed after the commencement of the germination, yet, as will be presently seen, he failed to discover the fungus in its perfect form. Animated with the like desire of discovering the true development of this curious production, PEREIRA bestowed much time and attention in its examination. He examined yeast at Messrs. HANBURY and BUXTON'S brewery in London, at various stages of the fermentation of both porter and ale, from a few hours to many. In the more advanced stages of fermentation, he observed that globules of yeast were frequently in strings or rows, apparently forming moniliform, often branched plants; but as the cells were very readily separable, he could not satisfy himself that the adhesion was otherwise than mechanical, such as is observed in the blood-discs, when they arrange themselves in series like money-rolls, and such as we sometimes perceive even in organic amorphous precipitates. His experience agrees with SCHLOSSBERGER, who states that he never could perceive a budding or bursting of the yeast cells, accompanied by a discharge of their contents, nor could he ever produce this by compression.

These curious brachial and other adjustments of the cells of yeast to each other, appeared to be the work of chance; it is, however, proper to add, that the artificial rupture of the cells has been effected by MITSCHERLICH, who also confirms TURPIN'S observation of the budding of the yeast cells.

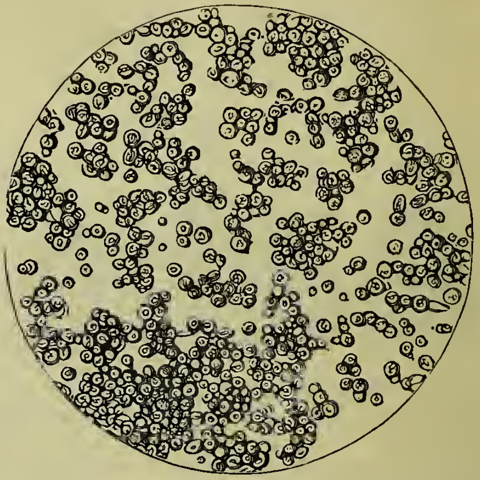
M. ROBIN, after describing the development of the sporules by budding, remarks:—Only this mode of propagation of the vegetal is known: its fructification in the air has not been seen, nor can it be seen, because it perishes at the part at which it is in contact with the atmosphere, so that it cannot yet be classed amongst the fungi which fructify only in the air, nor even among the algæ, from which it is separated by very many particulars, and which bear fruit under the water.

Dr. HASSALL, another zealot in the same cause, performed many diligent examinations of the yeast plant, and succeeded in tracing it through all the stages of its growth to its perfection. He classes the growth into distinct stages, as follows:—

First stage, or that of *sporules.*—In this, the ordinary state in which the yeast plant is met with, it consists entirely of sporules; these are for the most part separate, but sometimes feebly united in twos, threes, and even in greater numbers; they vary in size and form, some are several times smaller than others, and nearly all contain one or two nuclei, which are the germs of future sporules. Fig. 41 represents the yeast fungus in the first stage of its growth.

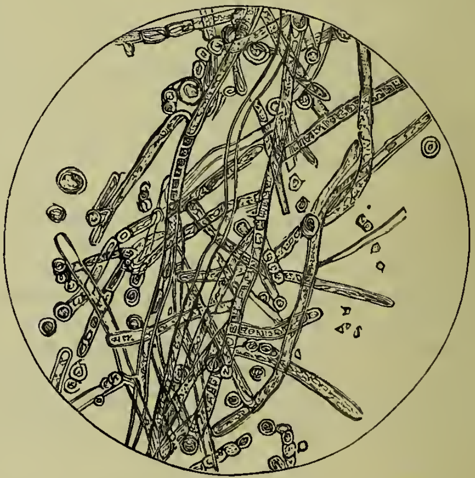
Second stage, or that of *thallus.*—After the lapse of some days, and under favorable circumstances, the sporules become much elongated; a division or a partition appears in each, on which account it is formed into two distinct cells; the extension still continuing, other septa appear, until at length, jointed threads—at first simple and undivided, and afterwards jointed—are formed, and the plant now exists in the form of root-like threads, or thallus. The yeast plant, in the state of thallus, constitutes *Mycoderma cerevisiæ* of DESMAGIERES. See Fig. 42.

Fig. 41.



Third stage, or that of *aerial fructification.*—After the lapse of a further time, vertical threads spring up from the thallus, Fig. 43; these, when the plant has reached its complete development, become branched, each branch bearing, at its extremity, a row of rounded and beaded corpuscles, which are about the size of the sporules, but differ from those bodies in their darker color and firmer texture. Occasionally, in the rows of beaded corpuscles, one cell several times larger than the rest is seen.

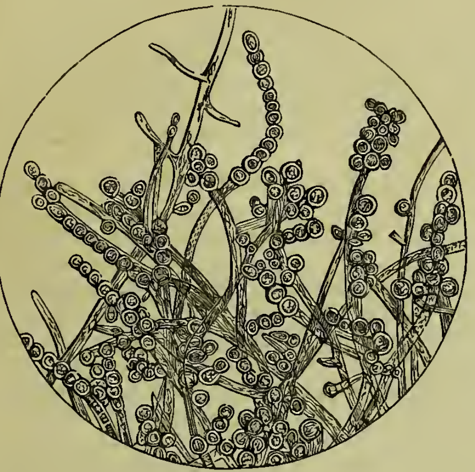
Fig. 42.



Such is a brief description of the development of the yeast plant in its several stages.

From a consideration of the structure of the sporules of the yeast plant, their evident fungoidal character their rapid growth, *et cetera*, HASSALL concludes that the reason why the true or aerial reproduction had never been discovered, was to be found in the fact, that the yeast being used always in the state of sporules, sufficient time was not allowed to it, under ordinary circumstances, to attain its full development, for which purpose, probably, many days would be required. To prove the validity of this inference, he placed, in an eight ounce bottle, a table-spoonful of malt, poured over this about four ounces of hot water, and partially closing the mouth with a perforated cork, set it aside for a fortnight. At this time he found that the aerial production had taken place, which other observers failed to detect. Hence the German algologist, Kurtzing, is in error, in regarding it as a confervoid production.

Fig. 43.



The plant, it appears, grows at the expense of the sugar, giving out carbonic acid, and leaving alcohol. The active part of yeast remaining after it has been well washed with water, consists of—

	Mitscherlich.
Carbon,	47·00
Hydrogen,	6·60
Oxygen,	35·80
Nitrogen,	10·00
Sulphur,	0·60
	100·00

It also contains a trace of phosphorus, and of fixed bases. Of this yeast, from two to three parts are required for the decomposition of one hundred parts of sugar; and if there be an excess of sugar, it remains unaltered after the fermentation.

That portion of the yeast which remains in the form of a deposit, after fermentation is over, is inefficient as a ferment. It appears, when examined under the microscope, to consist of the ruptured cells, and is unsusceptible of vegetation; so that, during the fermentation of sugar, a certain portion of the yeast plant dies, and is decomposed, the living plant being required to sustain the fermentative process. If more yeast be present than is required for the decomposition of a certain quantity of sugar, the deposit which is in that case formed consists partly of broken and partly of entire cells, and the latter retain their power of inducing fermentation. It would further appear, that the portion of the yeast which has become inert as a ferment, has lost the greater part, if not the whole, of its nitrogen; and certainly, one of the results of the changes which ensue during saccharine fermentation, appears to be the formation of ammonia, which, though so small in quantity as generally to elude observation, may be detected amongst the gaseous products.

For the formation of yeast or ferment, the requisites appear to be, the presence of sugar and of a nitrogenized principle in aqueous solution, and the contact of air. A solution of pure sugar undergoes no change, but the addition to it of any proteiniferous compound, with the access of air, induces fungous vegetation, and, with it, fermentation. Grape sugar, and some form of protein, are present in all sweet fruits, and their juices are accordingly susceptible of fermentation, although, as Gay-Lussac's experiments have shown, they also require the presence of oxygen. Grape juice carefully preserved from the contact of air, as when expressed in an atmosphere of hydrogen, or of carbonic acid, may be kept for months without change; yet, upon the admission of a few bubbles of air, or of oxygen, it presently begins to ferment, and when the process has once commenced, it continues. It has, however, been shown by Schwann, that a fermentable liquor, namely, one containing sugar and a nitrogenized principle, undergoes no change when the air which has access to it has been previously passed through a red-hot tube; Ure and Helmholtz have repeated the experiments with similar results. Hence it has been assumed that the germs or seeds of the fungi are present in the atmosphere, and only await the requisite conditions and food for their vegetation, which they find in saccharine and other liquors; and that the vitality of these germs is destroyed by a certain elevation of temperature. Yet in Gay-Lussac's experiments, a few bubbles of pure oxygen gas—in which, from the mode of its preparation, organic germs could not be supposed to exist—induced fermentation; and he further states, that on decomposing a portion of must excluded from air, by the voltaic current, fermentation ensued, apparently in consequence of the evolved oxygen; but Helmholtz could not obtain this result.

According to Mitscherlich, animalcules are also concerned in the phenomena of fermentation. Thus, if a little sugar be added to a liquor containing *infusoria*, the animalcules increase rapidly, and ferment is at the same time formed; on adding more sugar the multiplication of the animalcules ceases, but there is an increase in the production of the ferment.

Fownes remarks,—It often becomes a matter of great practical importance to have it in our power to excite the vinous fermentation, under circumstances in which ordinary yeast cannot be obtained. In making bread, for example, although the use of yeast may be avoided by employing what is called leaven, or dough which has already become sour, and partly putrefied by spontaneous change—a practice which has been followed from the most remote antiquity, and is still occasionally in use—the bread so made is always to be distinguished by a peculiar sour and nauseous taste and smell, and can never bear comparison with that fermented by yeast. According to the above-cited chemist, yeast of the most unexceptionable quality can be artificially produced at will.

BERZELIUS states, that although the reproduction, as it were, of yeast—the conversion of a small into a large quantity—is a very easy thing, yet to produce that substance from the beginning is very difficult. He describes a process for this purpose, on the authority of Dr. HENRY, and which consists in taking a strong infusion of malt, saturating it with carbonic acid, and then exposing it for some days to the proper fermenting temperature; when a small quantity of yeast is gradually formed and deposited, which may, by various contrivances, be made to give origin to a larger. Presently, the behavior of a malt infusion when left to itself, at a temperature of 70° or 80° Fahr., for some time, will be considered, from which it will be seen that the addition of carbonic acid is wholly unnecessary. Diastase, for instance, according to its peculiar condition, whether fresh from the germinated grain, slightly putrefied, or in a still more advanced state of that change, possesses the singular power, in the first case, of changing starch into dextrin, and ultimately into grape sugar; in the second, of causing the conversion of sugar into lactic acid; and in the third and last, of exciting the vinous fermentation.

Now, if common wheaten flour be mixed with water to a thick paste, and exposed, slightly covered, to spontaneous change in a moderately warm place, it will be observed to run through a series of metamorphoses which seem very closely to resemble those in the case of diastase.

About the third day of such exposure it begins to emit a little gas, and to exhale an exceedingly disagreeable sour odor, much like that of stale milk. After the lapse of some time this smell disappears, or changes in character, the gas evolved is greatly increased, and is accompanied by a very distinct and somewhat agreeable vinous odor; this will happen about the sixth or seventh day, and the substance is then in a state to excite the alcoholic fermentation.

A quantity of brewer's wort is next to be prepared in the usual manner, by boiling extract of malt with hops, and, when cooled to 90° or 100°, the decomposed dough before described, after being thoroughly mixed with a little tepid water, is added to it, and the temperature kept up by placing the vessel in a warm situation; after the lapse of a few hours, active fermentation commences, abundance of carbonic acid, having its usual agreeable pungent smell, is disengaged, and when the action is complete and the liquid clear, a large quantity of excellent yeast is found at the bottom, well adapted for all purposes to which that substance is applied.

In one experiment the following materials were used: A small handful of ordinary wheat flour was made into thick paste with cold water, covered with paper, and left seven days on the mantel-shelf of a room where a fire was kept all day, being occasionally stirred. At the end of that period three quarts of malt were mashed with about two gallons of water, the infusion boiled with the proper quantity of hops, and, when sufficiently cooled, the ferment added. The results of the experiment were, a quantity of beer—not very strong, it is true, but quite free from any unpleasant taste—and at least a pint of thick barm, which proved perfectly good for making bread. When the yeast alone is the object to which attention is directed, the hops may be omitted.

A moderately strong infusion of malt which has not been boiled, when suffered to stand in a warm place for some days, speedily becomes sour and turbid, and begins to evolve gas; this change rapidly progresses, carbonic acid is given out plentifully, and a deposit of thick, insoluble, whitish matter formed, which readily excites fermentation in a dilute solution of sugar: the supernatant liquid contains alcohol and traces of acetic acid.

When wort which has been boiled and hopped is set aside to decompose spontaneously, the change it undergoes appears to depend very much upon its strength: if weak, three or four days elapse before any action is noticed; a scum then collects upon the surface, and a brown flocculent substance precipitates, which is incapable of exciting fermentation in a solution of sugar, while the liquid gives off a flat offensive smell. Should the infusion experimented on be stronger, then the action is different; the liquid becomes turbid from the separation of a yellowish adhesive substance, a good deal of gas is very slowly emitted, alcohol is formed, and the deposit at the bottom of the vessel proves a pretty active ferment to sugar. The acidity of the liquid is trifling, and its smell is somewhat disagreeable. These differences in the behavior of boiled wort may also depend upon the quantity of hops added, which act as an antacid, and upon the length of time during which the ebullition had been continued.

The effect produced in a spontaneously fermentable liquid by vegetal acids, or acid salts, such as cream of tartar, is a curious subject of inquiry. From an experiment made upon some wort, it appeared that the result of such addition tends to the formation of lactic acid. We know that when the juices of grapes, currants, and gooseberries, are exposed to the air, the vinous fermentation commences apparently at once; whereas in an unboiled infusion of malt, which is destitute of these substances, lactic acid seems to be first formed, although ultimately the two fermentations proceed collaterally. It has been stated, when speaking of the spontaneous decomposition of wheaten dough, that an acid state preceded that in which it became an alcoholic ferment; if, in this condition, it be mixed with a dilute solution of common sugar, and the whole be kept warm for several days, it furnishes a sour liquid which is rich in lactic acid, and which gives with zinc a white crystallized lactate of this metal. There is a tendency in the liquid to run into the alcoholic fermentation, and to produce vinegar by a subsequent change; but still the quantity of lactic acid so formed is very considerable.

Common wheat-gluten, then, in its mode of decomposition strikingly resembles diastase; like that substance it runs through two different dynamic conditions. It is successively a lactic acid and an alcohol ferment. Is it too much to expect that it might, by proper means, be detected in a third condition, namely, as a sugar ferment, like diastase itself in the state in which it exists in malt? Is it not possible that diastase, as a definite proximate principle, has no more existence than yeast; that its powers are purely dynamic, and that it is, in short, nothing more than the gluten of the seed in one of its earliest stages of decomposition? This is an interesting inquiry, but its prosecution will be somewhat difficult, owing to the rapidity with which these changes follow each other. It must be remembered that no one has yet succeeded in getting diastase in a state fit for analysis. Having several times alluded to this substance, the Editor appends the following particulars with regard to it.

PAYEN and PERSOZ were the first to obtain diastase from barley malt. It may be procured from brewers' malt, but in greater quantity from germinated barley, carefully prepared for the purpose, in which the germ has been allowed to attain about the length of the seed. The malt is pulverized, and macerated in, or triturated for a few minutes with water, at the temperature of 70° or 80°. The pasty mixture is then strongly pressed, and the turbid liquor, which runs from it, filtered: the filtrate is then heated in a water-bath to about 170°, at which temperature the greater part of the foreign nitrogenized matter coagulates, and may be separated by filtration; the clear filtrate retains the diastase, and may be used for many purposes. Other bodies besides the diastase are also contained in the liquor, but they may, to a great extent, be separated by the addition of anhydrous alcohol, which forms a flocculent precipitate of diastase insoluble in that liquid. It should be collected and carefully dried at a low temperature; for, when heated in a moist state above 190°, its properties are materially altered. It may be further purified by a second solution in water, and precipitation by alcohol; if the solutions are brown, animal charcoal will decolor them.

Diastase may also be obtained without the aid of heat, but the process requires caution. The operation consists in triturating the finely-ground malt as before with a little water, pressing out the liquor, and carefully adding a little alcohol, so as to coagulate its albuminous contents without precipitating the diastase; the solution is then filtered, and the diastase separated by the further addition of strong alcohol. It may be purified by a second aqueous solution and alcoholic precipitation, and should be dried at a temperature not exceeding 100°, or in vacuo over sulphuric acid. Diastase is white, soluble in water and in dilute alcohol, but insoluble in strong alcohol. Its aqueous solution is tasteless, and soon becomes sour and decomposed. Its effect upon starch is entirely destroyed by boiling. It contains nitrogen; its ultimate composition, however, has not been accurately determined.

Although diastase thus prepared cannot be regarded as a perfectly pure substance, it nevertheless possesses a remarkable power of converting starch into dextrin and glucose—to such an extent, indeed, that one part of it is capable of modifying two thousand parts of starch.

The conversion of starch into glucose is slow; but its transformation into dextrin takes place rapidly, and becomes at once perceptible. If the reader will introduce a tepid infusion of malt—diastase—into a vessel filled with starch paste, the temperature of which is kept, as nearly as possible, at 160°, he will find that in a few minutes the change becomes manifest by the liquefaction of the mass. Now, if portions of the liquid be tested from time to time with iodine solution, which produces a blue coloration as long as any starch is present, it will be found that the intensity of the hue is quickly diminished, and that soon a point is reached when the complete cessation of any tinge indicates the total transmutation of the starch into dextrin; the transition of the latter into glucose is not accomplished under several hours. The mode in which diastase operates upon the starch is not known. We are at present only cognizant of the fact; but this fact is of great importance in a practical as well as a theoretical point of view. As science progresses, these recondite processes will have more light thrown upon them.

DISTILLATION.—The chief object of importance in this stage is the still; and no other article of manufacturing apparatus has undergone so much alteration. Whatever form or construction may be given to it, the philosophy of distilling rests upon the different degrees of volatility of the bodies subjected to the operation. By attention to this principle, several bodies of varied densities may be separated, if suitable means are adopted. It was known to the earliest alchemists that the more volatile a body, the less heat is required to convert it into vapor; and *vice versâ*, the temperature at which that body is liquefied is lower than what is required to effect the resolution of a liquid which boils at a higher temperature. By transmitting the vapor of these liquids simultaneously through a good condensing medium, the temperature of which is lower than the boiling point of the heavier, but not so low as the point at which the lighter boils, it becomes evident that the vapor of the heavier liquid will be condensed, while the other loses nothing of its acquired expansion. This is beautifully illustrated by the subject under consideration. The temperature at which water boils is universally known to be 212°; alcohol boils at 176° Fahr. If a mixture of these two liquids be introduced into a retort or still, the mixture will boil at an intermediate temperature, proportionate to the quantity of each liquid present; but the alcohol being the lighter is driven over in larger quantity at first, carrying with it some aqueous vapor: as the boiling continues more water is given off, until, at the end of the operation, nothing passes over but steam. When the mixed vapors are conducted through a tube placed in water below 212°, and not so low as the boiling point of the mixed liquid, the water is condensed, and the alcoholic vapor remains unaffected, till the temperature of the refrigerator is lower than 176°. The same thing happens in distillation with the ordinary apparatus. In the first and second volutions of the worm in the condensing tube, the aqueous portion is more or less condensed, and the spirit retains its acquired elasticity, till it traverses the worm to where the temperature is below its boiling point; then it becomes liquid. It was a great desideratum in the days of the early distillers to obtain a concentrated spirit, as at those times only the common still and worm were in operation, and the whole of the water eliminated with the alcoholic vapors was found in the receiver. By repeated distillations of the first products, a pretty concentrated spirit could be obtained; but this was effected at a loss of time, fuel, and alcohol.

To arrest the formation of acetic acid, as soon as the attenuation of the wort has reached its lowest point it is run into the still with as little delay as possible. According to the old methods, the wash is distilled in two large retorts or stills, each of about six to twelve hundred gallons capacity, suited to the size of the factory. The retorts are provided with a rotatory chain apparatus for preventing the lies from adhering to the bottom of the still, which, unless prevented, would deposit and become charred from the heat, and communicate a disagreeable taste to the spirit.

Previous to distillation, about one pound of soap is added to every hundred gallons of the wash. When the charge of wash is eight thousand gallons, the distillation is carried on as speedily as possible, without risk of it *running foul* till about two thousand four hundred gallons are drawn off. These constitute the *low wines*, or singlings, and are very weak, not averaging above 63° below proof on Dicas' hydrometer. The remainder of the spiritous product of the eight thousand gallons is received in another vessel for a further distillation. The singlings are redistilled, or *doubled*, in the second still, and the spirit drawn off till it begins to acquire a disagreeable taste and smell—these are what constitute the *faints*, and owe their peculiarity to an essential oil which is held in solution. The faints are collected in the faints-back, and mixed with the muddy part of the first distillation, water is added, and the whole redistilled. Very weak singlings are obtained, which, upon a second distillation, afford finished spirit.

Some distillers continue the first distillation as long as any alcohol comes over, and then subject the low wines to a second distillation in the spirit still. The first portions are more or less blue or muddy, and consequently are run into the faints-back. As soon as the spirit becomes clear, and devoid of a disagreeable odor, it is run into the spirit-back. The quantity of the spirit obtained in well-regulated distilleries, amounts to about three-fourths or even four-fifths of the low wines operated upon; faints are drawn over at the end of the distillation, and are turned into the faints-back, together with the first portions. These faints are mixed, as before stated, with a considerable quantity of water, and distilled, in order to free them from the disagreeable oil eviscerated by the husks of the grain.

A self-regulating bath is, in some distilleries, put in the capital of the still. The common Scotch stills have the capital fifteen to twenty feet high, to prevent the wash from boiling over into the worm; it is customary to strike the capital from time to time with a rod, and from the sound emitted, it is inferred whether it be empty, partially filled, or in danger of an overflow; in the latter case the fire is withdrawn, or damped by means of a spout near the furnace-door, and which is supplied with water from a cistern in the upper part of the building. When a very pure spirit is required, it is customary to dilute the liquor with water and submit it to a third distillation, in order that the distillate may not have the harsh taste of strong alcoholic liquids. In the improved stills, a liquid sixty per cent. over proof is obtained, even in the first distillation, and at a considerable saving of fuel, time, and labor, while the use of soap, *et cetera*, is unnecessary.

The usual yield of proof spirit from malt is between two and two and a half gallons per bushel. The largest amount of spirit procured from one quarter of corn is twenty gallons. As a general rule, the lower the heat at which the distillation is carried on, the purer will be the spirit. When an excess of soap has been used, and the distillation urged too rapidly, the distillate often possesses a saponaceous flavor, which is occasioned by its fatty particles being carried over mechanically in the vapor, and dissolved in the alcoholic liquid. The manner in which the soap acts to prevent the charge running foul, is as follows:—During fermentation, and subsequent transference of the wort into the still, small portions of acetic acid are generated, which decompose part of the soap, setting free the oily compound which rises to the surface of the liquor, and breaks the bubbles of vapor as they ascend through it from the bottom of the retort; hence the liquid cannot pass over unless the boiling be violently urged.

The average quantity of spirit obtained by the Irish distillers from a barrel of malt—twelve stones—is eight and a half gallons, Irish measure, or six gallons five pints and one and a half noggins, imperial measure, of twenty-four per cent. over proof by Dicas' scale.—*Donovan.*

Dr. URE performed several experiments, at the request of the Board of Excise, for the purpose of deciding a discussion which had taken place in Ireland, relative to the extent to which raw grain could be fermented; the most decisive of his results is the following: Three bushels of mixed grains were taken, consisting of two of barley, one-half of oats, and one-half of malt, which, being coarsely ground by a handmill, were mashed in a new tun with twenty-four gallons of water at 155°. The mash liquor drawn off amounted to eighteen gallons, at the density of 1·0465; temperature of 82° Fahr. Being set in a new tun, it began to ferment in the course of twelve hours, and in four days it was attenuated down to gravity 1·012. This yielded, upon distillation, in low wines, 3·22 gallons, and by rectification, in spirits, 3·05, while the quantity equivalent to the attenuation by the tables was 3·31; being an excellent accordance in such circumstances.

The inquisitorial system imposed by law upon our distilleries might lead a stranger to imagine that our legislators were desirous of repressing, by every species of annoyance, the fabrication of the fiery liquid which infuriates and demoralizes the lower population of these islands. But, alas! credit can be given them for no such moral or philanthropic motive. The necessity of the Exchequer to raise a great revenue, created by the wasteful expenditure of the state, on the one hand, and the efforts of fraudulent ingenuity, on the other, to evade the payment of the high duties imposed, are the true origin of that system.—*Ure.*

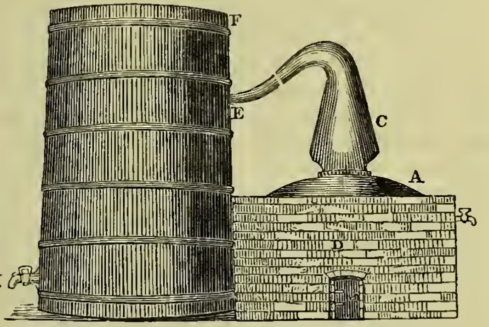
Examinations in distilleries are constantly being made by the officers of Excise. The first survey is at six o'clock in the morning, when the officers take their accounts and gages, and make calculations which occupy several hours; the second is at ten o'clock, when they inspect the whole premises, occupying a considerable time, frequently staying till the succeeding officer comes on duty; the third takes place at two in the afternoon; and the fourth, at six in the evening. At ten, an officer who has not been engaged in any of the previous examinations, makes his appearance, and prolongs his visit till six the next morning. In addition to these regular inspections, the distilleries are subject to frequent and uncertain visits of the surveyor and his general.

Before the fermented wort goes into the still, a calculation is made of the quantity of wash drawn from the wash-back, and which is first pumped into what is called the wash-charger. If the liquor in the charger exceeds the quantity in the back, the distiller has to pay on the higher amount; if it contain less, he must pay according to the wash-back, as being the larger quantity. When all the wash is transferred to the charger, its exit tap is unlocked, and the wash is allowed to be drawn off into the still; the charging and discharging tap of the still being fastened by the officers, there can be no transfer of wash but through the pumps. The first distillation from the wash is worked into the low-wine receiver, and the strength and quantity are ascertained by the Excise officer. The account of the low-wine affords a comparison with the quantity which the contents of the wash-back had been estimated to produce. This is then pumped from the receiver into the low-wine charger, and after the officer has performed his duty, it is permitted to be drawn off into the low-wine still, which is a distillation of the second extraction; the low-wine still then works into another cask, called the spirit-receiver; when that distillation is finished, the officer, reattending on regular notice for that purpose, takes the quantity and strength of the spirit therein, and upon the quantity so ascertained he charges the duty. If it happens that the actual quantity of spirit, after the distillation, differs from the hypothetical quantity ascertained by previous calculations, he gives to the Government the benefit of the doubt, and levies duty on the higher quantity, whichsoever that may be. The mode in which this double system of computation is likely to check improvements, forms a delicate subject, and therefore will not be further discussed. In distilling low wines, one portion of them goes into the spirit, and another into the faints-receiver; these faints are, in the next distillation, united with the low-wines from the succeeding wash-back, and are worked together; the united produce goes partly into the spirit cask, and partly back into the faints-cask. The operation is thus continued till all the backs are emptied. All these backs, chargers, receivers, *et cetera*, are secured by locks, the keys of which are kept by the Excise officer.

The still has been in use from a very remote period; but those in operation at present are quite different from the ones of former days. Changes in the construction of the still are chiefly the result of the onward course of science, and the increased requirements of the age.

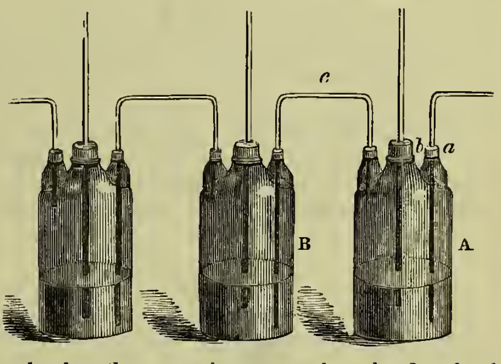
Fig. 44 is a drawing of the common still: A is the body incased in brickwork, D, and directly over the fire; C, the head attached to the condensing-worm, E, placed in the water-tub, F, where the vapor is condensed to a liquid which flows into a receiver at K. The still is of variable dimensions, from ten to five hundred gallons. This form of apparatus had been in use for a considerable period. WOULFE, having the principle of GLAUBER'S apparatus in view, was the first to apply the facts already cited, for obtaining strong spirit, and various other products of distillation.

Fig. 44.



This apparatus bears the name of the inventor to the present day. It is shown in Fig. 45, and consists of a series of bottles, placed in a range. Each of these bottles has three openings or necks; the first bottle is connected with the beak of the still by a pipe or tube, which passes through the neck, *a*, to within an inch or two of the bottom. A safety-tube is introduced through the neck, *b*, and dips into the liquid in the bottle. The bottle, A, communicates with the bottle, B, by means of a pipe or tube, *c*, bent at right angles; in the first it opens a little below the cork, but in the second it passes nearly to the bottom. The second is joined in a similar way to a third and fourth bottle, if required. This apparatus is in daily request in the laboratory, for the purpose of obtaining aqueous solutions of gaseous bodies. It was from it that M. EDOUARD ADAM conceived the idea of his complex still; and the same principle is to be observed in all the various modifications of stills constructed in the beginning of the present century, the most important of which will be described.

Fig. 45.



In this kingdom, the modifications in the construction of stills have been various. Previous to the year 1788, the old form of still was in general use. From the slowness of the distillation, a week elapsed before a charge was completely worked off, and even then the products were very dilute. At this period the Excise duty levied was according to the size of the still, and no further trouble was taken by the officers as to how the worts were made, except that they visited the distilleries occasionally, to observe if any other stills were in operation, or if larger ones were substituted for those which had been already gaged. About the above period an important revolution took place in the construction of this apparatus by a firm in Leith, by which the distillation was very much expedited. They lessened the height and increased the width of the still, to expose a larger surface to the action of the fire than could be done in the old form; the head of the still was enlarged in proportion to the quantity of vapor generated, and occasionally several outlets or pipes were inserted around the horizontal upper part, to facilitate the escape of the steam and alcoholic vapor into the condensing worm. This still could be charged, distilled off, and be ready for another operation, in the course of a few hours, instead of a week as before with the common still. Though the inventors preserved to themselves its exclusive use for about twelve months, yet such an important discovery could not escape the vigilance of competing neighbors, and hence it shortly afterwards became general in Scotland. The Excise, until they became apprised of the fact, were outwitted, the distillers, as might be expected, pocketing the duty which they otherwise should have paid for the excess of spirits distilled above the ordinary allowance to which the former method of gaging subjected them. The Excise duty, however, was soon altered, and year after year it increased; but the distillers, constantly upon the alert, were enabled to hoodwink the overseers appointed by Parliament, which was driven to the necessity of nominating a committee, in 1799, to investigate this branch of the Excise laws, and which furnished a lengthy report of the facts concerning the modes of distillation in Scotland. In consequence of this report the distillers were subjected to an Excise duty according to the capacity of the still, and on the supposition that it would be worked off and charged every *eight* successive minutes during the distilling season. Even this time was considerably shortened by the distiller; still, the amount of fuel consumed, and the consequent wear and tear, left it a matter of doubt whether they were gainers by it. The rapidity of this method was carried so far, that, in 1815, the last year of the license duty, a still of eighty gallons capacity could be distilled off, emptied, and be ready for a successive operation in three and a half minutes, sometimes in three minutes! A still of forty gallons could be drawn off in two and a half minutes. An alteration in the Excise laws at this time did away with the license duty, and the law became the same as in England, of levying duty upon the wash and spirits procured therefrom, which dispensed with the rapid mode.

In the meantime, the stills were constructed on the plan of those in use during the period of rapid distillation, namely, by having the bottoms wider than the English stills, in proportion to their size.

From the interest which, at one time, was attached to the Scotch still, on account of the ingenuity displayed by the inventors, and its being a source of much investigation to the Government committees, it may not be out of place to gratify the curiosity of the reader by introducing to his notice a drawing and brief description of the apparatus. As the general principles of the nature of the still have been already given, a recurrence to them is unnecessary.

The subjoined Figs., 46 and 46^a, represent a sectional and front view of the Scotch still, at the period when rapid distillation was popular amongst spirit manufacturers. E E is the body of the still, the bottom of which is about sixteen feet in diameter, and convex towards the middle; the depth of the still at the centre is about eleven feet, and the sides and bottom meet at an acute angle at the verge. The hollow bottom of the still is connected with the shoulder, B, by solder, or rivets, but in so firm a manner that the connection is air-tight; C, a rim, which serves to support the still, as likewise to protect it from the action of the

Fig. 46.

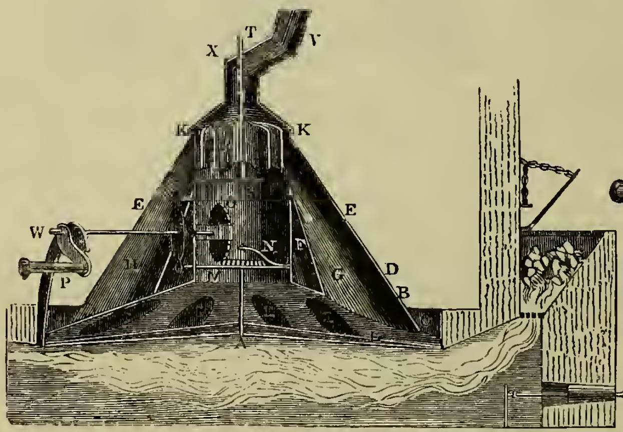
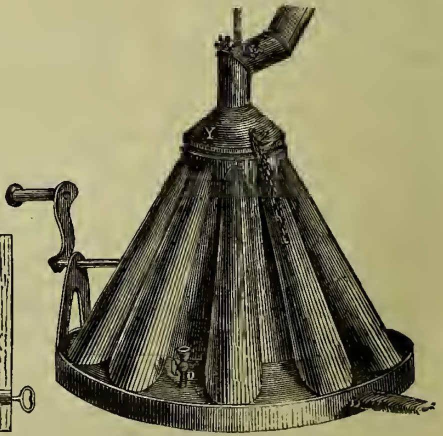
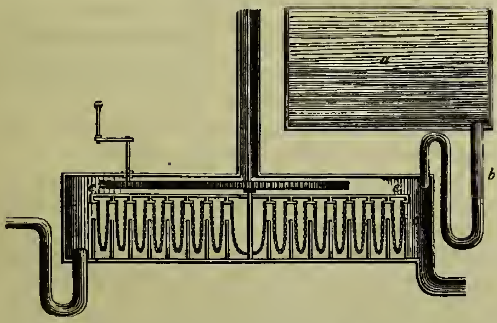


Fig. 46a.



fire. D is the discharging pipe, seen in the front view of the apparatus, but concealed in the section. In the shoulder of the still are several elliptical openings, to which are attached oblique conical tubes, that enter a cylinder which rises from the centre of the boiler; G is a vertical section of one of the pipes, which are soldered or connected at the bottom to the opening in the shoulder of the still; and F, a section of the central column; H is an exterior view of another of the side pipes; I I I I are lower openings of four others of these, and K K the top openings in the central column; L, an agitator within the still, to keep the bottom free from sedimentary matters,—a chain agitator was sometimes substituted, which, with a little alteration, was found to work much better; M, a vertical axis of the agitator, to which a horizontal toothed wheel, N, is attached; O is another such cogged wheel, but vertical, gearing into the wheel, N, so as to communicate its motion to the latter when required; P, a handle fixed upon the axis of the wheel, O, by which it is turned; W, support of handle and axis; R, a fan to break the froth formed by boiling; its axis rests upon the cross-bar, S. Motion is given to the fan by the vertical axis, T; this axis enters the large pipe that carries off the vapors, through a packed box, X, which is impervious to the escape of any steam or vapor; a similar box surrounds the axis of the wheel, O; V is the pipe communicating with the condensing-worm, and through which the vapors escape to be condensed. The funnel pipe, O, shown in the perspective view, serves to charge the still, and Y is the cover of the central column, which is held in its proper position by chains, as seen at Z.

Fig. 47.

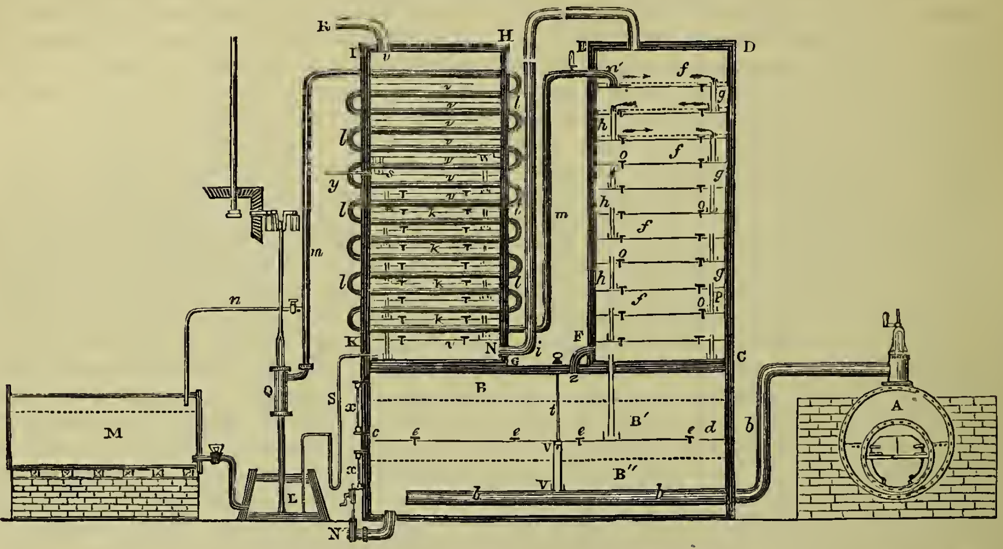


An adaptation of this still, by Sir Anthony Perrier of Cork, is shown in Fig. 47, in which the liquid to be distilled is made to flow gradually and continuously over the heated surface of the boiler, while it parts with its alcohol. The bottom of the boiler is divided by concentric partitions, which stand up sufficiently high to prevent the liquid from boiling over; these partitions have openings from one to another at opposite sides, so as to make the course a sort of labyrinth. *a* is the reservoir of liquor prepared for operation; *b*, a pipe descending from this reservoir, which conducts the liquor into the boiler at *c*, the commencement of the labyrinth, in flowing through which it progressively traverses the whole surface of the bottom, so that the full effect of the fire is exerted upon small portions of the liquid. This causes the evaporation to proceed with great celerity, and when the liquid has reached the discharge-pipe at the opposite side, it retains no spirit. The series of chains suspended from the bars, *e e*, which are supported by the central shaft, prevent the deposit of mucus and albuminous matters on the bottom of the still. A toothed wheel and pinion communicate motion to the bars, *e e*, through the shaft, and the chains sweep the compartments between the partitions as they turn round.

The first step towards obtaining the products of distillation in a concentrated state by a novel arrangement of the still, or rather condensing apparatus, was taken by Mr. Coffey of Dublin. In all the preceding stills, although the rapidity of distillation had reached the acmé of perfection, yet the great disadvantage of having the aqueous and alcoholic portions of the distillate mixed up, remained; and only by great trouble and repeated distillations and changing of receivers, a strong spirit could be obtained. Coffey's method was to insert two pipes in the first and second rounds of the condensing worm, which pipes were in communication with the body of the still. This simple contrivance insured considerable advantage, as a great portion of the aqueous vapors eliminated from the boiling liquid in the still, was removed from the alcoholic portion by being condensed in the first convolutions, and returned to the still instead of flowing into the receiver with the spirit.

Subsequently, Mr. Coffey patented another still, which has proved most serviceable to the distiller, as it gives, in continuous distillation, the strongest spirit that can be obtained on the large scale. Fig. 48 is a section of this still. The body of the apparatus consists of an oblong vessel, B, and two columns erected thereon, C D E F and G H I K. The first of these columns is called the analyzer, the second the rectifier. The whole is made of wood, lined with copper, and the wood being five or six inches thick, little or no heat is lost by radiation. The oblong vessel has a copper plate or diaphragm, *c d*, across the middle of it, which divides it into two chambers, B′ B″. This diaphragm is perforated with a great number of small holes, for the passage of the vapor upwards during the process, and it is also furnished with several valves, which open upwards, as shown at *e e e e*, whenever the vapor is in such quantity as not to find a free passage through the perforations. A pipe, V V, descends from this diaphragm nearly to the bottom of the lower chamber, into a pan forming a steam trap; and there is a valve on the top of this pipe, which can be opened or shut at pleasure, by means of a rod, *t*, passing through a stuffing-box on the top of the vessel. Glass tubes, at *x x*, show at all times the level of the liquor in the chambers, B′ B″. The column, C D E F, which is called the analyzer, consists of twelve chambers, *f f f f*, formed by the interposition of eleven copper diaphragms, *g h*, *g h*, *et cetera*, similar to the large diaphragm, *c d*; that is to say, these eleven diaphragms are perforated with very numerous holes, and furnished with valves, *o o o o*, opening upwards. To each of them is also attached a dropping pipe, *p*, by which the liquor is allowed to flow from plate to plate; the upper end of each of those pipes projects an inch or two above the plate in which it is inserted, so as to retain, at all times, during the distillation, a stratum of wash of that depth at each diaphragm. The lower end of each pipe dips a little way into a shallow pan lying on the diaphragm underneath, forming thus a steam trap, by which the escape of vapor through the pipe is prevented. The pipes are inserted at alternate ends of the diaphragm, as shown in the figure.

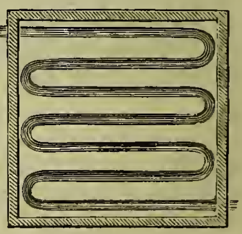
Fig. 48.



The column, G H I K, is divided, in a similar manner to that just described, into chambers, by interposed copper plates or diaphragms. There are fifteen chambers in this column; the lowermost ten, *k k k*, *et cetera*, constitute the rectifier, and its diaphragms are perforated, and furnished with valves and dropping pipes, precisely similar to those of the analyzer. The uppermost five of these frames form the finished spirit condenser, and are separated from the other ten by a copper sheet or diaphragm, without small perforations, but having a large opening at W, for the passage of spiritous vapor, and a dropping pipe at *s*. There is a neck about the opening, W, rising an inch or so above the surface of the diaphragm, which prevents the return of any finished spirit by that opening. Under the dropping pipe, *s*, is a pan much deeper than those of the other dropping pipes, and from this pan a branch pipe, *y*, passes out of the apparatus, and carries the condensed, but still very hot spirits, to a worm, or other refrigerator, wherein they are cooled. The chambers, *v v v v v*, of this finished spirit condenser, are formed of plain unperforated diaphragms of copper, with alternate openings at the ends, large enough both for the passage of the vapor upwards, and of the condensed spirit downwards; the use of these diaphragms being merely to cause the vapor to pass along the pipe, *m m*, in a zig-zag direction, and to be thus more perfectly exposed to its condensing surface.

In every chamber, both of the finished spirit condenser and of the rectifier, there is a set of zig-zag pipes, placed as shown in the plan, Fig. 49. Each set of these pipes is connected with the others by the bends, *l l l*, thus forming one continued pipe, *m m*, leading from the wash pump, Q, to the bottom of the rectifier, whence it finally passes out, and rising up, enters the top chamber of the analyzer, where it discharges itself at *n'*. M is the wash charger; L, a smaller wash vessel connected with it, and with the wash pump. This vessel is called the wash reservoir, and is not, strictly speaking, a necessary part of the apparatus; its use is to retain a sufficient reserve of wash, to prevent the apparatus being idle during the delay, which the Excise regulations render unavoidable, between the emptying of the wash charger and the refilling it from a new back.

Fig. 49.



The pump, Q, is worked continuously during the distillation, so as to supply the apparatus with a regular stream of wash. It is so constructed as to be capable of furnishing somewhat more than is necessary, and there is a pipe, *n*, with stopcock, by which part of what is pumped up may be allowed to run back, and the supply sent into the apparatus regulated.

A is a steam-boiler, having nothing peculiar in its construction. The steam from it is conveyed into the bottom of the spent wash receiver by the pipe, *b b*, which, after entering the receiver, branches into a number of smaller pipes, perforated with holes, by which the steam is dispersed through every part of the wash in which they are immersed. These perforated pipes are not shown in the drawing.

Mode of Action.—When commencing an operation, the wash pump is set in motion, to charge all the zig-zag pipes, *m m m*, until the wash passes over into the analyzers at *n'*. The pump is then stopped, and the steam let into the bottom of the apparatus by the pipe, *b b*. The steam passes up through the chambers, B'' B', and by the pipe, *z*, into the analyzers, whence it descends, through *i*, to the bottom of the rectifier at N. It then rises through the chambers, *k k*, enveloping the zig-zag pipes, and rapidly heating the wash contained in them. When the attendant perceives, by feeling the bends, *l l l*, that the wash has been heated in several layers of these pipes, perhaps eight or ten layers—but the number is not of much moment—he again sets the pump to work, and the wash, now boiling hot, or nearly so—and always in rapid motion—flows from the pipe *m* at *n′*, and passes down from chamber to chamber through the dropping pipes, in the direction shown by the arrows in a few of the upper chambers. It may be here observed that no portion of the wash passes through the small holes perforated in the diaphragms which separate the chambers. These holes are regulated, both in number and size, so as not to be more than sufficient to afford a passage for the vapors upwards, under some pressure. The holes, therefore, afford no outlet for the liquor, which can only find its way down in the zig-zag course indicated by the arrows. It is therefore obvious, that the wash, as it passes down, is spread into strata as many times as there are diaphragms, and is thus exposed to the most searching action of the steam constantly blowing up through it. As it falls from chamber to chamber, its alcohol is volatilized by the steam passing upwards; and by the time the wash has reached the large chamber, B, no trace of the spirit remains. The wash, as it descends from the analyzer, accumulates in the large chamber, B′, until it becomes nearly filled, which, when perceived to be the case, by the inspection of the glass tube, the attendant opens the valve of the pipe, V, and discharges the contents of B′ into the lower compartment; then shutting the valve, the wash from the analyzer again accumulates in B′, and, when it is nearly full, the contents of the lower chamber are discharged from the apparatus altogether, through the cock, N′, and the charge in B′ let down by opening the valve, V, as before; thus the process goes on so long as there is any wash to supply the pump.

When all the wash is gone, a quantity of water is let into the reservoir, L, and pumped through the pipes, *m m*, to finish the process, and obtain the last portions of alcohol. This winding up of the operation by sending water through the pipes, takes place on the distillation of every back of wash, in consequence of the Excise regulation, which requires the distiller to keep the produce of each back separate from that of any other. Were it not for this regulation, the distillation would go on uninterruptedly, so long as there was any wash in stock; the addition of water for winding up would be necessary but once during the distilling period, and the manufacturer would save much time and fuel at present wasted by these interruptions.

It has been already said, that in the ordinary course of the operation, the wash is stripped of all its alcohol by the time it has reached the bottom of the analyzer; but, as a precautionary measure, the chambers, B′ B″, have been superadded, in each of which the spent wash is exposed for about half an hour to the action of the steam blowing through it. There is a small apparatus —not shown in the engraving—by which a portion of the steam in the chamber, B″, is condensed, cooled, and made to flow constantly through a sample jar, in which is an hydrometer, or, what is better, two glass bulbs, one of the spec. grav. 1·00, and the other, 0·998. The attendant knows all is right when the lighter of these bulbs floats in the sample; hence the chamber, B, may be emptied without any risk of loss.

The course of the wash being understood, that of the steam will require very little description.

The steam, as it rises, is first blown through the charges of spent wash in the lower chamber of B, thence it passes up through the layers of wash on the eleven diaphragms of the analyzer. In its course it abstracts from these layers of wash, their alcohol, depositing in its place an equivalent of water. After traversing the whole of the analyzer, the vapor, now containing much alcohol, passes, by the pipe, *i*, into the bottom of the rectifier, and, as it ascends, it envelopes the pipes *m m*, heating the wash, and simultaneously parting with its more watery portion, which is condensed, and falls, in a state of ebullition, on the several diaphragms of the rectifier. By the time the vapor reaches the passage, W, in the bottom of the finished spirit condenser, it is nearly pure alcohol; and as it is condensed by the wash in the pipes, and falls on the diaphragm, it is conveyed away by the pipe, *y*, to a refrigerator. At the top of the spirit condenser is a large pipe, R, which serves as a vent for the incondensable gas which is disengaged in the process, and this pipe also communicates with the refrigerator, so that, should vapor at any time be sufficient to pass out of the apparatus, no loss is sustained beyond the waste of fuel caused by condensing that vapor by the water of the refrigerator, instead of the wash of the condenser.

The liquor formed on the several diaphragms of the rectifier, after the vapor, passing up from plate to plate, has blown through it, descends to the bottom in the same manner as the wash falls from chamber to chamber in the analyzer: but this condensed liquor still contains a portion of alcohol, and it is conveyed by the pipe, S, to the pump, Q, by which it is raised up with the wash, to be again distilled.

A thermometer at *m′* shows the attendant the temperature of the wash as it issues from the pipe, *m m*, into the analyzer, which is the only guide he requires for managing the operation; for, when the temperature is what it should be, nothing can go wrong in the work. Whenever the thermometer indicates too high a temperature, more wash should be let into the apparatus, and *vice versâ*—the quantity being regulated by the tap and the pipe, *n*. It would seem, however, that very little nicety is requisite on this point. Experience has proved, that the fluctuation of a few degrees above or below the proper heat is of little consequence, and that it is very seldom found necessary to alter the supply of wash.

The water for supplying the boiler passes through a long coil of pipe immersed in boiling-hot spent wash, by which means it is raised to a high temperature before it reaches the boiler. It will be seen that the vapor passing through this apparatus is all condensed by the wash, not water; and, therefore, no heat is wasted, as in the common process. The consequence of this is, that about three-fourths of the fuel used with the common stills are saved, a matter of very important consideration in a national point of view.

According to the common process, it requires twelve pounds of coal to distil a gallon of proof spirits—when coals of a superior quality are employed, and the stills are scientifically constructed, less will suffice—of which, as has been said, nine pounds are saved by the new system; and assuming the whole quantity of spirits distilled in the empire to be thirty-six million gallons, which—colonies included—is not over the mark, the saving of fuel arising from the new methods of distilling, which, no doubt, will be soon universally adopted, will amount to one hundred and forty thousand tons of coal per annum.

Very few persons have any idea of the enormous size of some of the distilleries in the United Kingdom. One of Mr. COFFEY'S stills, at Inverkeithing, works off two thousand gallons of wash per hour, and one which the inventor has subsequently erected at Leith, for the same proprietors, upwards of three thousand gallons. There are several of equal magnitude, and it is stated that those now at work, or being erected, are capable of distilling half a million gallons of wash per day—this wash yielding, on an average, from eleven to twelve per cent. of proof spirit.

The great difficulties distillers in general had formerly to contend with, are no longer encountered, as the advancement of science necessarily improves every branch of industry. No one can observe the difference of the condensation of aqueous and alcoholic vapors, and look at the various apparatus of the present time, without coming to the conclusion, that chemistry, in particular, has conferred very great improvements in distillation.

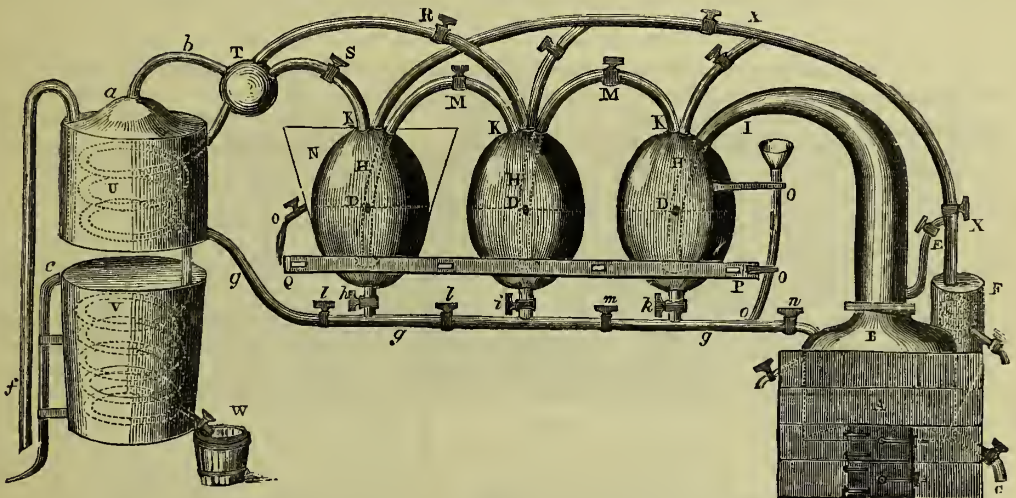
The continental savans were the first to offer improved forms of stills. Relative to the distillation or production of ardent spirits, the improvements are principally of two kinds: firstly, relating to the construction of proper apparatus, by the use of which spirit of a superior strength is obtained from the first distillation, without the trouble of repeated distillations, as in the older methods; and secondly, the knowledge acquired in employing the most economical quantities of materials from which spirits are obtained in this country, as well as in the proper fermenting operations to which such materials are subjected previous to distillation.

M. POISSONIER, in the year 1779, proposed a modification of the common still, and deemed his plan to be the ultimate pitch of perfection of which the still was susceptible. His modification would most likely have come into general use, had it not been for the better and more ingenious invention of M. ADAM, an obscure person of Nîmes, who was devoid of scientific knowledge, and, though a distiller, was ignorant of the art which he improved. Being an auditor of a course of chemical lectures at Montpelier, during which the merits of a WOULFE'S apparatus as a condenser were discussed, he conceived the idea of constructing a still in which the principles of the apparatus of GLAUBER and WOULFE should be applied in the condensation of the vapor. Accordingly, he diligently applied himself to the construction of an apparatus on these principles, and, after repeated additions and alterations, it was found to answer the intended purpose. He took a ten years' *brevet*, or patent, in 1801, for his invention, and since that time a complete revolution has been effected in the art of distillation. About the same time, M. SOLIMANI obtained a patent for another form of distillatory apparatus. This gentleman was a physician at Nîmes, and formerly lecturer on chemistry and experimental philosophy, and disputed the priority of his invention with M. ADAM; but his patent is dated a few days later in July, 1801, than ADAM'S. Various other modifications of the still and condensing apparatus were introduced, the most important being that of M. BERARD, which he patented on the 16th of August, 1805.

ADAM'S still, however, continued to be most in use, not so much on account of its merits—for it was considerably inferior to SOLIMANI and BERARD'S—but owing to the quarrelsome disposition of the patentee, whose cupidity led him to suppose, as his brevet specified that the whole of the alcohol could be obtained from wines when distilled in his apparatus, that the other inventions were an infringement on his rights; and the lawsuits to which he exposed those using any new invention, prevented the general use of any other than his own. This litigiousness of M. ADAM, however, became afterwards his just corrector; for, after realizing a handsome fortune by his own distillery and the proceeds of his patent, he became so immersed in lawsuits, which ultimately proved unfavorable, that, with the expenses and costs of these heavy cases, he was completely reduced.

Fig. 50 is a drawing of ADAM'S still: B is the body of the still, incased in brickwork, and is heated by the furnace, A. The head, I, of the still carries off the vapor to a series of egg-shaped vessels of copper, H, H, H, the first of which it enters at the top, and terminates at the bottom in a perforated rose, like that of a watering-pot, the holes being about an eighth of an inch in diameter. The first vessel is connected with the second, and the second with the third, by the pipes, K, M, proceeding from the top of each, and terminating at the bottom of the next, in the form of a rose, similar to the pipe, I, the tubes fitting air-tight into them. They are supported on a framework, Q P, the wider end being uppermost. D, D, D are cocks, to show when they are half-full. The last vessel—here the third—is furnished with a bucket, N, soldered to its upper end, and filled with water, to condense the vapor; the hot water is drawn off by the stopcock, O. When the still is furnished with four or more oval-shaped vessels, the last two have refrigerators attached to them; if strong spirit be not required, the third may be dispensed with. The pipes, S, R, furnished with stopcocks, connect the second and third vessel with the globe, T, from which the worm in the covered vessel, U, proceeds. V is a large tub, which contains the second worm, being a continuation of the one in the vessel, U, and is filled with cold water by means of a water-pipe, entering at the bottom, though not shown in the figure; and as the water gets warm, it is discharged by the pipe, *c*. Another pipe, *a b*, issues from the head of the vessel, U, and is inserted in the globe, T, a continuation of which, though not expressed in the figure, connects this globe with the body of the still, or with either of the egg-shaped vessels, at pleasure; *ggg* connects the vessel U with the body of the still, as also with H, H, H, by means of the branching pipes from their bottoms, which are furnished with stopcocks, *h, i, k*; the stopcocks, *l, l, m, n*, in the pipe *ggg*, serve to regulate the connection with either of these vessels, as occasion requires it. The pipe and stopcock in the shoulder of the boiler regulate the proper quantity of wine to be introduced; and C, another pipe and stopcock, serves to run off the *vinasse*, or spent wine, from the still, when all the spirit has been eliminated. Another pipe, X X X, connects the three vessels, as well as the capital of the still, with a small worm placed in the vessel, F, the connecting branch pipes being furnished with stopcocks, to open or close a connection with any of the vessels. O O is a funnel pipe, which serves to charge the apparatus with *repasse*, or weak brandy, and is joined with the first, H, and the frame, Q P, by iron stays. The whole of the still and condensing apparatus is constructed of tinned copper, and the pipes connected by solder.

Fig. 50.



Operations are begun by opening the stopcocks, *l, l, m, n*; also, the pipe in the shoulder of the boiler, and closing the cocks, *h, i, k*; the vessel, U, is then filled with wine from the storehouse, through the supply pipe inserted in the cover, by means of a forcing pump, till the wine flows out by the pipe in the shoulder of B; this is then closed, and the cocks, *k, i, h*, opened in succession, till the wine flows out at D D D, the stopcocks, *n, m, l*, being closed as the still and first and second vessels are filled in succession. The pumping of the wine is continued until the vessel, U, is nearly filled; afterwards the refrigerators, N and V, are replenished with cold water. Everything being thus prepared, all the lower cocks are closed, and the upper stopcocks, M, M, R, S, opened, in order to allow a free passage for the vapor; the fire is then urged on till the liquor in the still begins to boil. The first portion of vapor is richer in spirit, and this passing into the first H, by the capital I, is condensed. The wine in this vessel—which is heated by the vapor rising from the boiler—contains a greater proportion of alcohol, on which account it boils quicker, and cannot reach as high a temperature as the liquid in B. The eliminated vapor from the first H, in consequence of the low temperature at which it is generated, contains less water, and this being condensed in the second, renders the wine which it contains much stronger than that in the first, and boils at a still lower heat. The more aqueous portion of the vapor from the second H, passing off by the connecting pipe, K M, is partly condensed in the third, while the surcharged alcoholic vapor enters the condensing worm in the vessel, U, through the pipe, S, where it is condensed, and flows out into the receiver, W. This is tightly covered over to prevent evaporation of the alcohol; and in order that the stream of liquid condensed may be seen, a glass pipe connects the lower end of the worm and the receiver. As soon as the distilled product, when examined by the hydrometer, shows a diminution of strength, the receiver is changed, and the weaker liquor, or *repasse*, is collected by itself, and submitted to a second distillation. The strength of the liquor in the boiler, B, or in any of the condensers, may likewise be ascertained by means of the pipe, X X X, which proceeds from the last, and communicates with the small worm, F, beside the body of the still; from each of the others, as also from the capital, pipes open into it, and as these are each furnished with stopcocks, the vapors from any particular condenser, or the still, may be liquefied in the small worm, F, the other communications being cut off. The spirit as it flows out at the end of this worm is received in a testing glass, and examined by the hydrometer, or by other means. When the liquor in the body of the still is exhausted, the fire is withdrawn, the other communications with the oval-shaped vessels and great worm are cut off, and the cock, C, opened to draw off the *vinasse*, or residue. If it also appears that the liquid in any of the condensers is exhausted, it is run off to the body of the still by turning the stopcocks appended to it. The still is next charged by allowing the unexhausted liquor in H, H, H, to flow in through the pipe, *ggg*, and the remainder, sufficient to fill the boiler as before, is supplied from the vessel, U. H, H, H may be half filled with brandy, or *repasse*, through the funnel pipe, O O; after which the lower taps are closed, and the upper ones opened as before, and the distillation continued. During the transmission of the alcoholic vapor through the wine vessel, U, the contents become heated, and some spiritous vapor is given off, which may be conducted into the body of the still, or any of the condensers, as deemed desirable, by the pipe *b*, the continuation of which is not expressed in the drawing.

When weak spirit is required, the communication with the third H is cut off by closing the stopcocks, M, S, and opening R, and when an extra strong liquor is required, a fourth condenser is supplied; for, according to the statements of the patentee, the more condensers that are furnished, the better and more completely will the rectification be effected. The body of this kind of still is stronger than ordinary, in consequence of the pressure from the egg-shaped vessels, which, of course, renders the expansive force of the vapor greater.

Fig. 51.

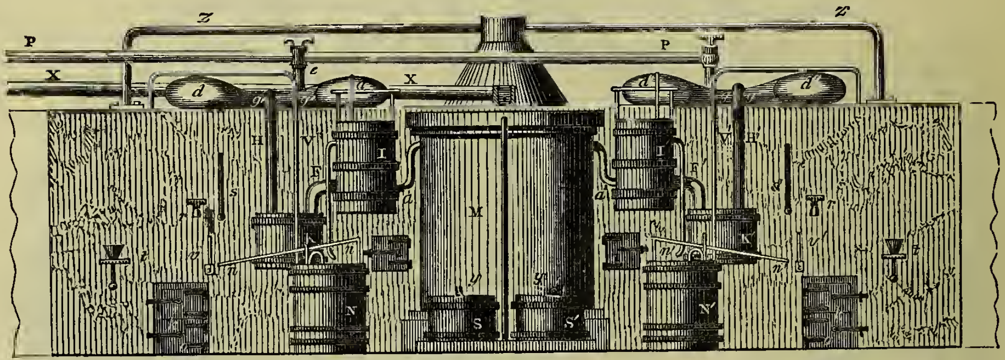
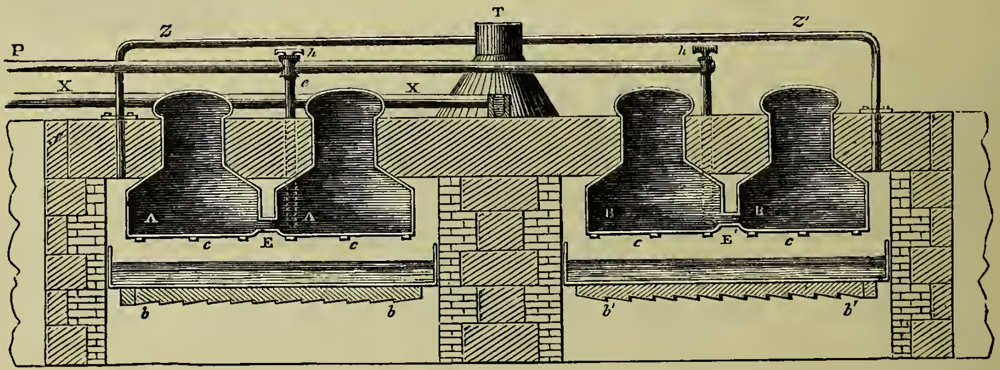


Fig. 52.



An elevation of the apparatus of Solimani is represented in Fig. 51, of which Fig. 52 is a section. The distillation is effected by the heat of boiling water. Four stills constitute the set; these are A, A, B, B, in the section, placed two at each side of the chimney, T. Each pair of stills is connected at the bottom by the pipes, E, E′; the body of each still is about four feet square and eighteen inches deep, and rests upon stout iron bars, *c c c*, firmly fixed in the walls of the furnace. *d d d′ d′* are the necks of the stills; they measure about three feet in breadth, and are long enough to rise above the stone vault, *f*, which protects the stills from view in Fig. 51. The heads are rather low, and the curvature, *g g g′ g′*, rather wide; they are soldered to a large pipe, H H′, which conducts the alcoholic vapor to the copper vessels, K K′, forming a part of the condensing apparatus. Some of the vapor is condensed in these vessels, and forms a liquid layer on the bottom, through which the remaining vapor has to force a passage. F F′ are large pipes for carrying off the uncondensed gas into the vessels, I I′, wherein is contained the condensing apparatus, or *dephlegmator*. Another small pipe, not shown in the figure, carries off the vapor from I I′ into the condensing medium, immersed in water contained in the stone cistern, M; and the small pipes, *a a′*, supply the cold water to the vessels I I′ from M.

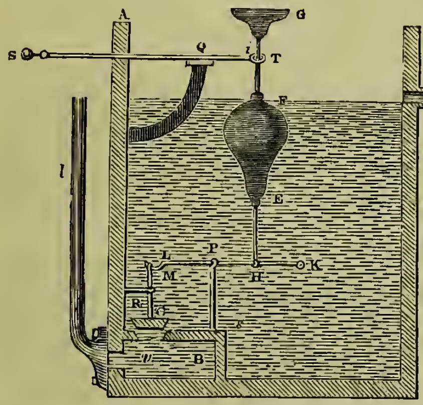
The stills are charged with wine through the main pipe P, which branches into them. By turning the stopcocks of this pipe, either pair of stills may be charged with wine, as the pipe, *e*, and the termination of P, reach nearly to the bottom of the body of the stills. The pipe, X X, supplies the large cistern, M, with cold water.

The condenser in each of the vessels, I I′, is kept cool by a self-acting apparatus, that admits the water from the cistern, M, in the requisite proportion to cool the parallelogram condenser.

The stills are heated by two boilers, about ten feet long and four and a half wide, which contain about eight to twelve inches of water in depth. *b b b′ b′* show a portion of the flue, which, at the fire, is about eight inches square, and gradually gets narrower as it approaches the chimney. The length of the flue from the fire to the chimney is about thirty-six feet, being brought several times back and forth under the boilers, that no heat may be lost. *z z′* are pipes for carrying off the steam into the chimney.

During the time the stills are in the course of being charged, the water in the boilers is raised to a temperature of 212°, and the steam which is generated, circulating around the stills, heats them so as to bring their contents to a boiling temperature in a very short time. The alcoholic vapor that rises flows down through H H′ into the vessels, K K′; part of it is here condensed, and the remainder which continues rarefied enters the first condenser through the large pipe, F F′. All the condensed liquid that is formed in this refrigerator flows back through the pipes, F F′, into K K′, where it collects till it rises as high as the bend of the attached siphons, when it flows into the large covered tanks, N N′. After the condensed weak and impure spirit has accumulated in N, it is pumped into the stills by means of the pumps, *n n n′ n′*, through the pipes, V V′, to undergo a second distillation. *i i′* are doors, by which to enter when any repairs are required by the boilers, *et cetera; k k′*, the doors of the furnaces for heating the boilers, and *o o′*, the ashpits. The pipes which discharge the spent wine from the stills are seen at *r r′*, and the gage, or glass tube, *s s′*, shows what height of liquid they contain. The funnel pipes, *t t′*, serve to introduce water into the boilers, which are furnished, like the stills, with glass gages, *v v′*, to show the height of water inside.

Fig. 53.



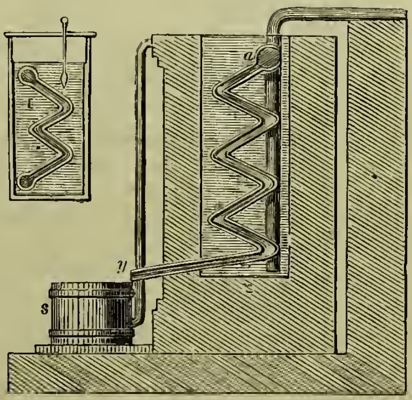
A, Fig. 53, is a section of one of the vessels, I, on one side of the condensing apparatus. B is a box fixed on the bottom, having a valve, C, in its upper part, of sufficient weight to resist the force of the stream of water entering the box by the pipe, *l*, from the large condensing trough. E F is a floating ball, bearing on its upper stem, G F, a basin, G, for the reception of weights. The lower stem of the float has a ring at the end, H, through which a sliding rod, K L, passes; this rod has a weight at the end, K, and a hook at L, which passes through the ring in the upper end of the rod, M, attached to the valve, C; K L is supported in the centre by the upright, P; R is a horizontal rod, which retains the valve, C, in its proper position by means of the stem of the latter passing through a ring at the end of R. A sliding rod, S T, is inserted in the side of the vessel; this rod has a ring, *i*, at its end, through which the upper stem of the float, E F, passes, and is supported by the arm, Q. The principle of the working depends on the rarefaction of the water when heated, and on the proportionate decrease of specific gravity. Weights are placed on the basin, G, to counterpoise the float at the exact temperature at which it is desirable to have the water. When the water gets hotter than this, the float descends, and pressing on the lever rod, K L, at H, raises the valve, C, when the water from the pipe, *l*, enters; when sufficient water has entered to cool down the vessel to the proper degree, as regulated by the float, the valve closes.

In case the float is found not to act properly, or that the water rises considerably above the temperature to which the weights on the basin correspond, the rod, S T, is to be pushed further into the vessel, which moves the lower end of the float towards K, and by this means greater force is applied to raise the valve C, in order that cold water may enter.

The condensing apparatus, or dephlegmator, in the vessels I I′ and M, in Fig. 51, consists of two broad sheets of tinned copper soldered together, so as to leave only one-sixth of an inch between them. In the vessels I I′, the dephlegmator forms four inclined planes, and in M M′ it is composed of six. These are the more advantageous on account of the extent of surface which is exposed to the condensing action of the strata of water. Figs. 54 and 55 show the position of these condensers.

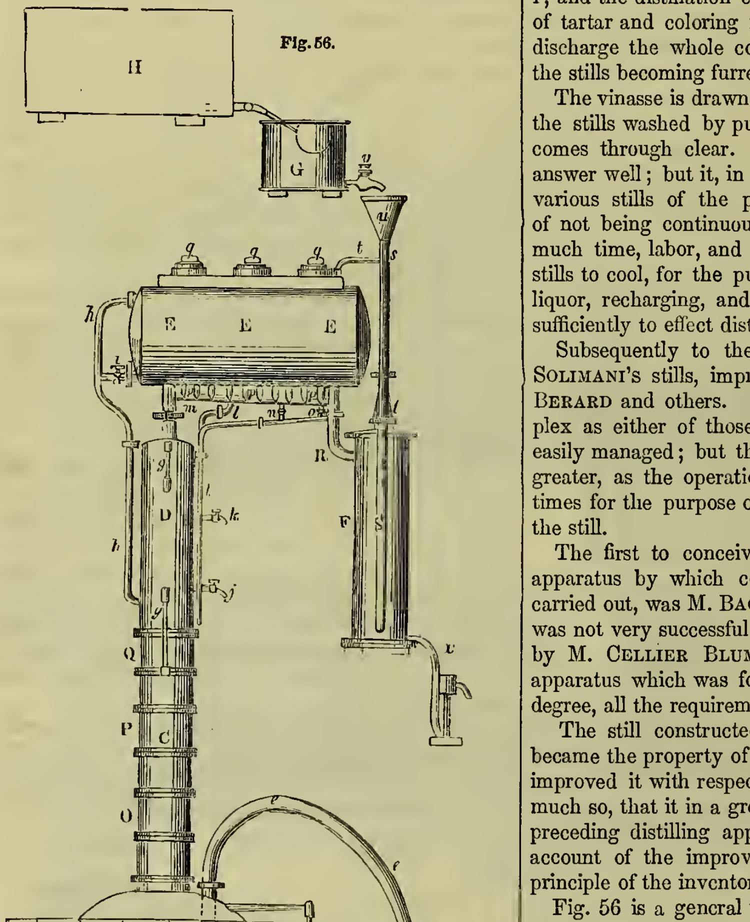
Having described the still and condensing apparatus, the manner of working will now be shown. The boilers being replenished with water to the depth of about eight inches, the fire is urged under them; during the time this is being done, wine runs into the still through P and *e*—Fig. 51—till it reaches the proper height, as

Fig. 54. Fig. 55.



indicated by the gage *s*, when the taps of the supply pipe are turned off. As soon as the water begins to boil, the contents of the still are likewise heated, and the vapor produced is forced to descend by the pipe, H, into the vessel, K, where some of the aqueous portions are condensed. The remaining portion of the vapor traverses the layer of liquid in its passage into the condensing vessel, I. Here the excess of steam is condensed, and flows back into the vessel, K, through the pipe, F; and when the weak and impure spirit collects in this to that extent that it rises as high as the bent siphon tube, it is discharged into the tank, N, whence it is again returned to the still by the pump, *n n*. But very little spirit is condensed in I I′, when the apparatus in this vessel for the regulation of the supply of cold water is properly attended to, and the strong alcoholic vapors pass off into the condensing vessel, M, where they are liquefied, and flow out into the receiver, S. When the liquor in the tank, N, appears exhausted, it is no longer returned into the still, but is rejected as useless, and fresh quantities of wine are run in by turning the stopcocks of the pipe, P, and the distillation continued, till the accumulation of tartar and coloring matters renders it necessary to discharge the whole contents, so as to guard against the stills becoming furred.

Fig. 56.



The vinasse is drawn off by turning the taps, *r r′*, and the stills washed by pumping water into them till it comes through clear. This apparatus was found to answer well; but it, in common with ADAM'S and the various stills of the period, retained the great evil of not being continuous in its operations, and hence much time, labor, and fuel were lost, by allowing the stills to cool, for the purpose of discharging the spent liquor, recharging, and again raising the temperature sufficiently to effect distillation.

Subsequently to the introduction of ADAM'S and SOLIMANI'S stills, improved ones were announced by BERARD and others. BERARD'S still was not so complex as either of those mentioned, and it was more easily managed; but the loss in fuel was considerably greater, as the operation had to be arrested several times for the purpose of discharging and replenishing the still.

The first to conceive the idea of constructing an apparatus by which continuous distillation might be carried out, was M. BAGLIONI. His attempt, however, was not very successful; but the subject was taken up by M. CELLIER BLUMENTHAL, who constructed an apparatus which was found to possess, in an eminent degree, all the requirements.

The still constructed by BLUMENTHAL afterwards became the property of M. DEROSNE, who very much improved it with respect to continuous distillation; so much so, that it in a great measure superseded all the preceding distilling apparatus. The following is an account of the improved still of DEROSNE, on the principle of the inventor.

Fig. 56 is a general view of the continuous distillation apparatus. It is composed of seven principal parts —namely, the boilers, the distilling column, the rectifying column, the condenser and wine-warmer, the refrigerator, the vat where the wine is contained, and the vessel which determines the flow of wine into the apparatus. Of these, A and B are the boilers, encased in masonry or brickwork. The fire is applied under A, and the extra heat is communicated to B by the flue passing under it in its way to the chimney; C is the column of distillation; D the column of rectification; E E the condenser and wine-heating vessel; F the refrigerator;

G is a vessel that furnishes the wine to the refrigerator—this vessel supplies itself, by means of a stopcock, from the store-vat, H, where the wine to be distilled is kept. The cock of this part is regulated by a floating ball, which closes it when the liquid rises in G. I is a tube of communication, conducting the alcoholic vapors of the rectifying column, D, to the worm in the condenser, or wine-heating vessel.

a is a stopcock, which carries off the spent wine of the boiler, A. When the operation is in progress, this cock is always open, and the exhausted wine flows off continually. *b* is a gage-pipe, which indicates the height of the liquid in the boiler, A; *c*, a safety valve or pipe, to show the pressure on the boiler, A; *d*, a stopcock, which allows the liquid from the boiler, B, to flow into the bottom of the boiler, A; *e e* is a tube that conducts the alcoholic vapors formed in the boiler, A, to the bottom of the boiler, B; the vapor, in passing through B, heats the liquid and condenses in part. *f* is a gage, to show the level of the liquid in the boiler B; *g*, *g*, level gages, indicating the height of the liquid in the compartments of the rectifying column, D; *h*, a tube, conducting the wine of the lower part of the condenser, E, to the topmost beveled plates in the interior of the distilling column; *i* is a stopcock, by which all the heated wine in the wine-heating vessel, or condenser, E, flows into the column, C, when a distillation is coming to a termination; *l l* are tubes, adjusted to the wine-warmer—the one descends as far as the lower compartment of the rectifying column, whence it rises again to the fifth; the other tube descends as far as the third compartment, and rises again above the second compartment. At the point of curvature of each, stopcocks *j* and *k* are fixed, intended to draw off, at will, the small portion of the condensed liquid brought back into the rectifier. *m*, *n*, and *o*, are tubes connected with the inclined pipe, *p p*, at one end, and the pipes, *l*, *l*, at the other. The three communications serve to produce a brandy of more or less strength. If it be required to obtain a stronger spirit, the alcoholic vapor that is condensed in the worm, S, is entirely reconducted to the rectifier, D; and, that this may be attained, it is only required to open the stopcocks, *n* and *o*; a spirit less strong is obtained on closing the stopcock, *o*, and a still weaker product on closing the stopcock, *n*; for the liquid formed in the worm of this cylinder flows off to the refrigerator, F, together with the stronger alcoholic vapor. *p p* is a pipe for receiving the whole of the alcoholic liquid condensed in each of the revolutions of this worm. *q q q* are closed openings in the upper part of the wine-warmer, which admit a person for the purpose of cleaning it. R is a tube conducting the alcoholic vapors not condensed in the wine-warmer to the worm of the refrigerator, F, where they are wholly liquefied; *s*, a tube which supplies the wine from the reservoir, G, to the lower part of the refrigerator, F. *t* is a tube which conducts the wine from the upper part of the refrigerator, F, to the upper part of the wine-warmer, E. *u* is the funnel-opening of the pipe, *s*, conducting the wine from G to the refrigerator; *v*, a stopcock, regulating the flow into the tube, *t*; *x*, a tube conducting the finished spirit from the refrigerator—it is so constructed, as appears in the figure, that an areometer adjusted to it always indicates the strength of the brandy. Having described the apparatus, it will be necessary to say a few words in explanation of the complex parts.

The interior arrangement of the distilling column is represented in Fig. 57. The surface of the liquid descending through this column is greatly increased by flowing in a thin stratum over the several plates successively, and the alcohol it contains eliminated with great facility by the ascending hot vapor. There are three openings, O P Q—Fig. 56—for cleaning the inside. Ten pair of copper plates are enclosed in this cylinder, and placed in such a zig-zag way as to recline downwards alternately, as seen in the section; the liquid, entering at the top, falls over each of the plates in succession, thus making a longer course, and becoming more exposed to the hot vapor.

Fig. 57.

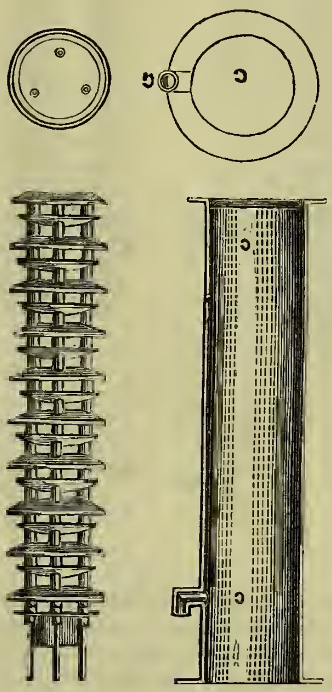


Fig 58 is a sectional, and Fig. 59 an exterior view of the rectifying column. Six inverted vessels occupy the interior, and are so arranged that the alcoholic vapor is forced to traverse a thin layer of liquid in each. The condensed liquid returns to the column, C, and the uncondensed vapor passes onwards to the worm in the first condenser by the pipe, I.

In these figures the position of the pipes, L L, will be better understood; in the front view one is represented descending to the lower and rising again to the third vessel, and the other coming to the third and mounting again to the second, and the sectional figure shows the communication of those pipes with the interior of the cylinder. G G are cases for the glass gages; and the sketches at foot are bird-eye views of the position of the respective tubes, here indicated by the dark spots, and the letters, H, M, K, J, and L.

Fig. 58.

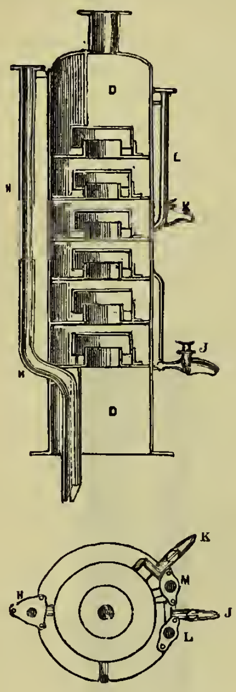
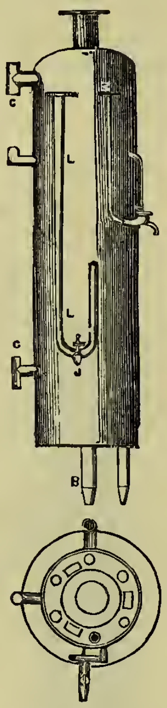


Fig. 59.



Figs. 60, 61, and 62 are details of the condenser, E, the first being an end view, the second a longitudinal, and the third a transverse section at *x′*, Fig. 61.

At each revolution of the worm, in Fig. 61, it communicates with the canal, *p p*, by a short connecting pipe. The wine enters from the pipe, *t*, shewn in the upper part of Fig. 56, and percolates small holes, as seen at *y y* in Fig. 61, over the worm, which it thereby cools sufficiently to condense most of the aqueous part of the vapor passing through it. Fig. 63 shows the arrangement in the refrigerator, S; and the cut appended, a bird-eye view of the top of this column. In these figures, the same letters indicate the same parts as in the general view, Fig. 56.

Fig. 63.

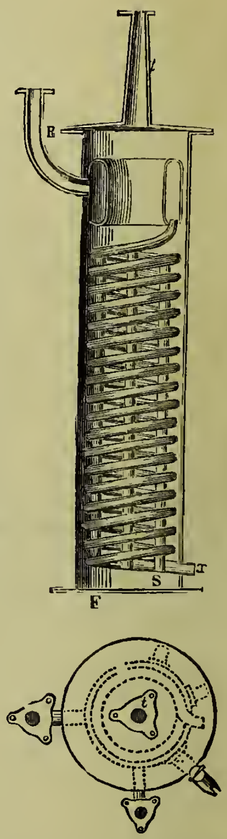


Fig. 60.

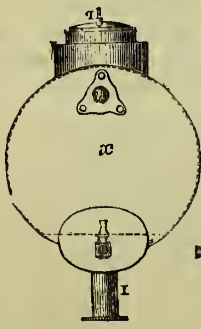


Fig. 61.

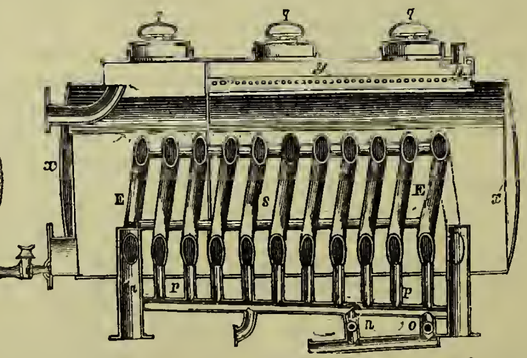
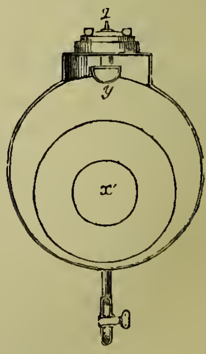


Fig. 62.



Referring, therefore, to Fig. 56, in connection with the parts shown in detail,—when operations are to commence, the boiler, A, is filled with wine through K, till within two or three inches of the top, as indicated by the gage, *b*; the fire is lighted, and the stopcock, *v*, opened, and the wine allowed to flow into the refrigerator, F, thence into the condenser, E; and when this vessel is filled, the liquid flows through the overflow pipe, *h*, into the distilling column, C, and ultimately to the boiler, B, until it rises to within five or six inches of the top of the gage pipe, *f*, when the cock, *v*, is closed. As soon as the liquid in A boils, alcoholic vapor escapes by the pipe, *e*, into the bottom of the boiler, B, where it is at first condensed, and thereby the liquor in this vessel becomes richer in spirit. Shortly, the liquor in B, in consequence of heat it derives from the traversing vapor, and its being richer in alcohol, begins to boil; part of the vapor rising through the distilling column and rectifier is condensed, while the uncondensed portion passes into the condenser through the pipe, I. When the liquid in the condenser becomes so hot that the hand cannot rest in contact with the outer case, the stopcocks, *a*, *d*, and *v*, are opened, and the wine allowed to flow till it reaches the boilers, B and A. As it descends through the distilling column, it is divested of the greater part of its alcohol by the ascending vapor; during its stay in the boiler, B, almost all the remaining quantity is removed, and the very last traces are separated in the first boiler, so that it is completely exhausted as it flows off by the waste stopcock, *a*.

It is found, however, that the charge entering into the first boiler from B, if allowed to run off at the full bore of the discharge-cock attached to boiler A, would retain small quantities of alcohol. If the alcoholic liquid remained always in a higher stratum in the boiler, then the tap, *d*, might be left open; but, in consequence of the boiling of the liquid, no such division can be expected. On this account, therefore, it is absolutely necessary to shut the discharge-cock of boiler A, for a longer or shorter time, while the liquid is in a state of ebullition, and to slacken the fire while the spent liquor is drawn off from the boiler.

Another still was contrived to carry out the principle of uninterrupted distillation by M. ST. MARC, a veterinary surgeon attached to the personal staff of Bonaparte. After the battle of Waterloo, ST. MARC turned distiller in France, and, about the year 1823, he removed to England. Here he, and a few others, formed a company for the fabrication of brandy from potatoes, and erected large works near London; the project failed, after three years' operation on a very extensive scale, leaving the speculators minus some forty or fifty thousand pounds.

ST. MARC, however, was not idle during the time the works were extant, for, by attention to his views on continuous distillation, he effected many valuable improvements in the form of his still. He completed this article in 1827, and obtained a patent for the United Kingdom; he then disposed of it to some London gentlemen, and returned with the proceeds to his native country.

This still came into great request among the principal distillers of London, Bristol, and other chief towns, where it had been reputed to work with great satisfaction. For the distillation of wash, however, it ranks far behind COFFEY'S. It is said, that at the establishment of Messrs. NICHOLSON at Clerkenwell, one of these stills produced one thousand gallons of gin hourly, the cleansing and flavoring processes proceeding at the same time. It was in great demand, also, for the distillation of rum in the West Indies, and several other English colonies, as, by its use, considerable outlay in fuel, puncheons, freight, and shipping charges were dispensed with.

Fig. 64.

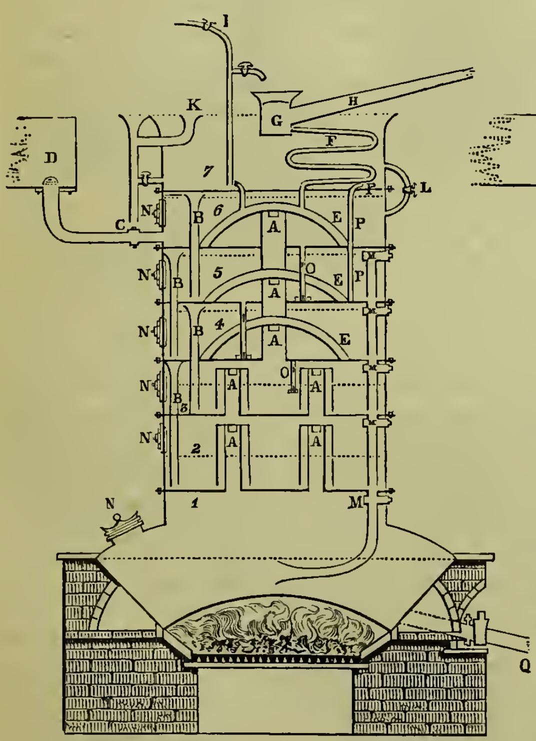
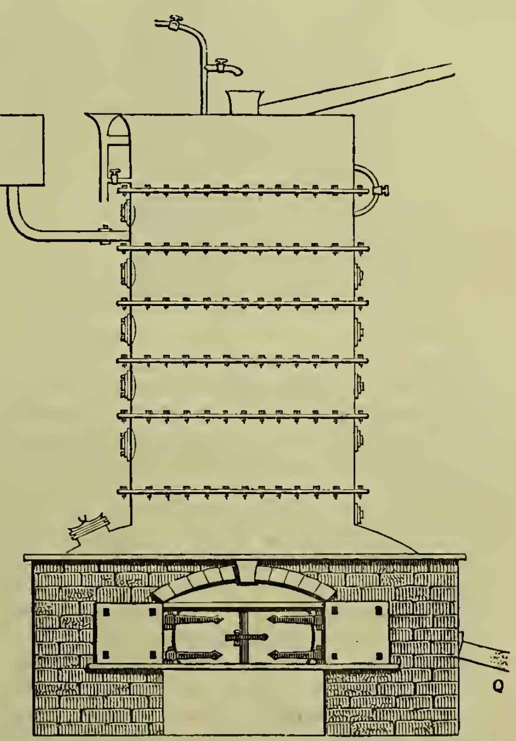


Fig. 65



Figs. 64 and 65 are sectional and front engravings of the still. It consists of seven coppers, placed one above the other, and numbered in the section, 1, 2, 3, 4, 5, 6, 7, of which six contain the wash or liquor to be distilled, and the seventh or upper one, water. The coppers, which are held together by flanges and bolts, communicate with each other by the double tubes, A A, through which the vapor ascends, and also by the pipes, B B, by means of which the wash descends from one copper to another in succession, beginning with the uppermost but one, N 6, into which it is introduced by a pipe and tap, C, from the wash-charger, D. The lowest or first copper, which constitutes the body of the still, and receives the heat of the fire, does not differ from the ordinary boilers, but the second and third coppers each contain four of the double tubes, A., and two of the pipes, B. The fourth, fifth, and sixth coppers have likewise the pipes, B, but have only one double pipe, A, in each, placed under hemispherical domes, E E E, constructed upon, and tightly flanged and bolted to the coppers that have just been mentioned. Six spiral tubes, or vertical worms, F, of which only one appears in the engraving, conduct the vapor from the upper dome through the water in the top division; these communicate with the chamber, G, capped by a small dome and pan, which is kept replenished with cold water, and the portion of vapor remaining uncondensed passes out to the common condensing worm, by the large pipe, H. I shows a pipe and stopcocks for conveying water to the top copper, No. 7, and chamber, G, and any waste water that may be used for scalding or cleaning the backs is carried off by the pipe, K, which is furnished with a branch pipe and stopcock. Water is conducted from the upper copper through the pipe and stopcock, L, to the several lower compartments into which it is introduced by means of the stopcock, M, appended to each; the water is used for bringing down the wash at the close of a back, as well as for cleaning the coppers. A man-hole, N, is furnished opposite to the pipe and stopcocks, M, to admit of their being thoroughly cleansed, and also to make repairs.

Having described the apparatus, it only remains to give a brief account of the operation. In the words of MOREWOOD:—

The first three coppers—of which the second and third only are intersected with double pipes—distil almost at the same time; the lowest, being that submitted to the action of the fire, operates on the others by the discharge of its vapor, which, ascending by means of the pipes, passes into the wash, and is there condensed, infusing its caloric into that liquid, which is thereby quickly brought to the boiling point. The uncondensed portion of vapor from the second compartment passes into the third with similar effect. The new vapor, necessarily stronger than the first, ascends into the fourth section, where it is received under a semispherical dome, which prevents it communicating directly with the cold wash contained in that copper. In this place the more aqueous portion of the vapor is condensed, and during this transition it yields its latent heat to the wash which surrounds the dome, bringing it to a higher temperature. The most volatile or spiritous portion, which passes into the fifth section, experiences the same change as the vapor in the fourth dome, and so on to the uppermost — the alcoholic vapor becoming stronger as it traverses every succeeding dome. The condensed portion in each dome returns through the coppers to the third chamber, and meeting with the ascending hotter vapors, they are partially redistilled in their progress. In the third copper a second distillation commences, giving off anew its alcohol.

To explain why the watery vapor is forced to return to the third copper, and is there found totally separated from the alcohol, it is sufficient to state, that water does not boil under a heat of 212° Fahr., while alcohol boils at 173°. When, therefore, the watery and alcoholic vapors rise, and are successively received in one or more atmospheres of from 200° or 190° to 174°, the aqueous vapor becomes separated from the alcoholic, and is condensed, and the latter alone passes out to the worm, and thence to the receiver at the desired strength.

From the foregoing particulars, it is evident that a large portion of the spirit is distilled by vapor or steam, and is, consequently, more pure than that obtained by the ordinary apparatus. If, therefore, all the bad flavor arises from long and violent exposure of the wash to the action of the fire, this process, as well as those already described, is calculated to obviate entirely that injurious effect, and to yield a spirit wholly divested of any empyreuma. One distillation only is effected by the fire; this is immediately succeeded by two vapor or steam distillations, and, subsequently, by four purifying consecutive processes, which divest the spirit of all impurities, and it comes over, at one operation, of the strength of 35 or 40 per cent. over proof, by SYKES' hydrometer.

A still of seven compartments, such as described, will produce spirit no stronger than 35 or 40 per cent. above proof; but, by increasing the number of coppers or sections, a much stronger liquor might be obtained by a single operation.

To ascertain the precise time for charging, after the exhaustion of the wash in the lower copper, it is only necessary to open what is called the proof tap placed in its side; and if the vapor issuing from it will not ignite on the application of a candle, it is evident a fresh charge is wanting. The discharge of the spent wash from the lowest vessel, the supply from the next copper to replace it, and the opening of the tap in the pipe, communicating between the charger and the top of the still to admit more wash, are all the work of about a minute, during which distillation never ceases.

The advantages of this apparatus are numerous, but may be briefly stated to consist in the saving of about two-thirds of the fuel usually consumed; an increased produce, by economizing what is lost by evaporation in the three compartments, with their pumpings, *et cetera*, in the ordinary system; a considerable saving of labor, there being but one furnace, and one tail-pipe, instead of three or sometimes four; to which may be added, the advantage of dispensing with low wines and faints' receivers and chargers, together with their connections and pumps, and the power required to put them in operation.

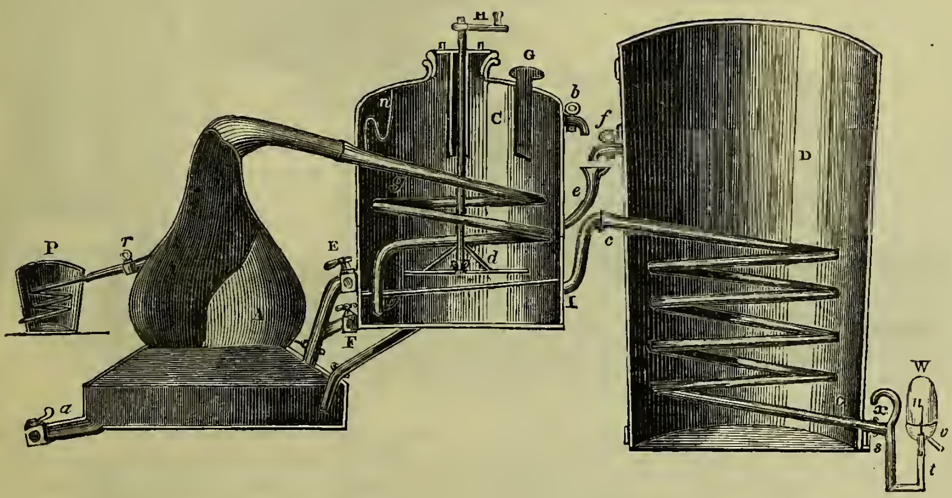
A safe of a superior nature has been constructed by Mr. SHARPE, one of the patentees. It is attached to the end of the worm, and holds a large glass cylinder, in which a thermometer is suspended; at each side of this cylinder are two smaller ones, in which are placed hydrometers, one for ascertaining the strength when *above*, and the other when *below* proof. The safe is so ingeniously contrived, as to enable the distiller to see the strength and color of the spirits, and also to take a sample, which, however, is registered against him upon a dial, and no spirit can be surreptitiously obtained, while it serves to prevent fraud both on the proprietor and the revenue.

The Germans employed, and still use on a small scale, an apparatus for the distillation of the fermented extract of malt, similar to Fig. 66, and which bears the name of DORN'S still.

The principal parts are the body of the still, A, the wort-warming vessel, C, and the condenser, D. The still is furnished with a discharging-cock, *a*, and a small pipe with stopcock, *r*, is inserted in the head, which pipe is connected with the end of a small worm in the tub, P. C is an iron or copper vessel, furnished with a double bottom, the one twelve inches above the other. In the upper part of this vessel are contained a few coils of worm, *g g*, the lower end of which passes downwards through the first bottom to within one or two inches of the other. An opening at the top of the preparer receives an agitator, H, which may be turned by the hand; a cross bar, *d*, at the end of this upright rod, skims the interior bottom of any sedimentary matter which may deposit on it. The opening, G, serves to charge the vessel with liquor; E and F are communications between both compartments of the vessel, C, and the body of the still, for the purpose of supplying it with the liquor contained in both these parts for distillation; *b* is an overflow-pipe and stopcock, by which it is ascertained when C is replenished. A pipe, I, issues from the far end of the lower part of the vessel, C, and is connected with the second worm, *c c*, in the large worm-tub, D. Another pipe, *e*, enters the preparer for the purpose of cleaning it with water at the termination of the distillation; the water is run into the boiler of the still, and drawn off at the discharge-cock, *a*. A pipe from an adjacent cistern, or reservoir, supplies the large tub, D, with cold water, and from this tub water is supplied to the pipe, *e*, through the stopcock, *f*.

An apparatus is furnished at the end of the worm, as it issues from the tub, in order that the flow of the liquor may be observed, and its strength noted at the same time. It consists of a tube, bent at right angles, as at *s t*, the upper part of which terminates in a curve, *x*, through which the air of the worm is expelled. The arm, *t*, is terminated in a basin, holding an inverted glass jar, W, in which a hydrometer, *u*, is placed, and floating in the spirit, in order to tell the proper strength. The pipe, *v*, carries off the finished spirit into the tank, where it is collected.

Fig. 66.

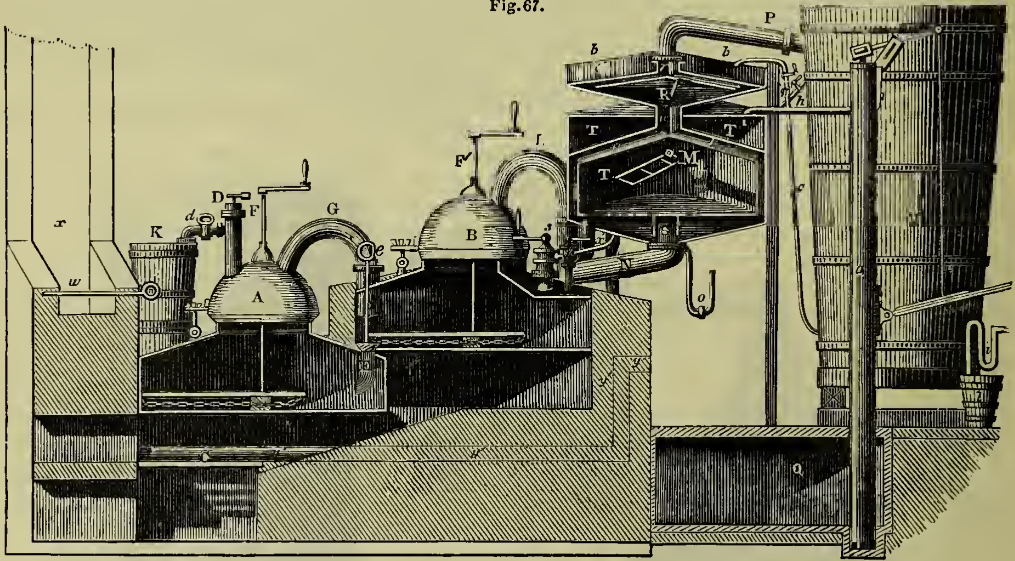


Operations are commenced by filling the preparer, C, with liquor, through the pipe, G, till it flows out at the stopcock, *b*, after which the cock, E, is opened till the still is filled to the overflow-pipe, which regulates the amount of liquor to be introduced, but which is not seen in the section. When this happens, the cock, E, is closed, and the vessel, C, filled to the proper height, then G is closed by a screwed cap or plug, and the furnace lighted under A. As the alcoholic vapor rises, it is partly condensed in the few coils of worm in the vessel, C, the liquid falling down to the bottom compartment; and the liquor in the vessel is heated by the latent heat of the vapor. As the liquor collects in the bottom part of the vessel, the remainder of the uncondensed portion of vapor gurgles through this liquid, which further deprives it of aqueous vapor; the portion uncondensed issues through the connecting-pipe, I, to the large worm in the condenser, where it becomes wholly liquefied; the excess of liquid in the lower part is allowed to flow into the still by the pipe, F. The charge in the still, when the whole of the alcohol has been expelled, is emptied through the discharging-cock, *a*, a fresh supply of the heated liquor in C introduced as before, and a second operation commenced—taking the precaution to slacken the fire while this part of the work is going on. The small condenser attached to the boiler or still, is to test whether the charge is wholly exhausted, and the small pipe, *n*, permits the escape of the air in the worm and lower part of the compartment in C.

Since the introduction of a better apparatus, DORN's is seldom used by the large distillers; it is, however, met with in small establishments, and where brandy is rectified.

The apparatus generally employed throughout Germany for the distillation of fermented worts, *et cetera*. is that represented in section in Fig. 67, and known as PISTORIUS', from his improvements and additions. In this figure, A and B are two boilers, connected by the pipe, G, which conducts the vapors formed in A into B. These boilers are each furnished with an agitating chain apparatus, F, F′. C is the fire-grate under the boiler, A, and the excess of heat is rendered available towards heating the other boiler by the flue winding under it before entering the chimney, *x*. D is a kind of safety-valve attached to the first boiler, and is furnished with a stopcocked pipe, *d*, that communicates with a small worm in the condensing tub, K; this contrivance is intended to test when the charge in the boiler is divested of the whole of the alcohol. The boiler, A, is charged from the contents of the second boiler, B, by means of a connecting-pipe, E, having a valve appended, the handle of which is seen at *e*. A large pipe, L, issues from the head of the boiler, B, and is connected with another pipe, N, of a larger calibre, having another smaller pipe, S, connected with the other end. The alcoholic vapor from the two boilers, A and B, passes through these tubes into the rectifying vessel, M, supplied with a second bottom, from which descends a vertical cylinder over the pipe, S, nearly to the exterior bottom. *r r r r* indicate the course of the vapor through the vessel, M; this passage is made of sheets of copper of nearly the same breadth as the vessel, soldered to an end plate of a few inches in breadth. The remaining parts of the vessel, noted by T T T, are charged with wash for the purpose of heating it before distillation. The spiritous vapor, on passing through this rectifying vessel, loses a great portion of water by condensation; but the chief quantity is separated in the double conical space, R, which is surmounted by a vessel of the same form, *b b*, filled with cold water from the large condensing tub. The pipe, P, conducts the uncondensed alcoholic vapor to the large condensing worm in the tub, V. The liquid formed in the passage *r r r* and R, collects at the bottom of the vessel, M, so that the vapor entering by the pipe, S, has to pass through it. When it accumulates, it is run into the boiler, B, by a connecting-pipe, *x′*, which is closed and opened at pleasure by means of the valve, *y*. *s* is the valve attached to the pipe which conveys the fermented wash from the compartments, T T T, in the vessel, M, to the boiler, B. The pipe, *c*, supplies the conical condensing vessel, *b b*, with cold water, and the pump, *a*, raises the fermented wash from the tank, Q, beneath, and discharges it into the vessel, M, by the pipe, *h*. When the space in the interior of M requires cleaning, water from the condensing tun is run in through the pipe, *m*, by turning the stopcock. *o* is a siphon tube, through which the air of the apparatus is expelled, when the fire is lighted under the boiler, A; it is closed by the stopcock when the alcoholic vapor reaches thus far.

Fig. 67.



The waste caloric from the furnace is made to warm the water employed in mashing the grain, by a pipe, *y′ y′*, leading from the fire, that carries off the heated vapor for that purpose. The spirit is received in a peculiar manner from the lower end of the worm, as will be explained after describing the mode of operation.

The fermented liquor to be distilled is pumped up into compartments, T T T, in the case, M; the valve, *s*, of the pipe connecting the space, T, with the boiler, B, is then opened, and the wash introduced into this boiler, whence it is allowed to flow into the first boiler by opening the valve, *e*, of the connecting-pipe, E. This valve is left open till the liquid rises to the proper indication, as shown by a gage in front, but not seen in the figure; *e* is then closed, and all the other taps, leaving a free course for the vapors to flow off to the condenser. When this is done the fire is lighted. After a short interval, the liquor in A begins to boil, and the vapor passes over into B, whose contents are also raised to ebullition, which takes place at a lower degree in consequence of the quantity of alcohol it receives from the preceding.

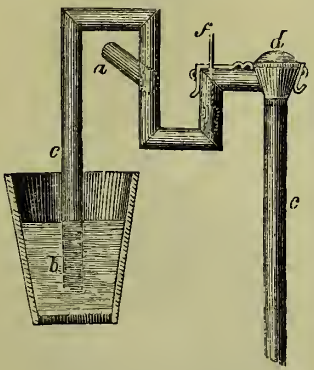
The alcoholic vapor from B passes over by L through the pipe, N, into the rectifying spaces, *r r r r*, where the excess of the watery vapor is condensed, and falls to the bottom of M. This liquid being the product of the former two distillations is very rich in alcohol;

and when it accumulates sufficiently to cover the end of the pipe, s, the hot steam from the boilers bubbling through it disengages a vapor surcharged with alcohol; thus a third distillation is effected. When the liquor is present in too large a quantity, the valve, *y*, is occasionally opened to run it into B. The uncondensed portions rise and pass from the conical-shaped condenser, R, into the large condensing worm in the vessel, V, where they are completely condensed, and flow out at the lower end of the worm into the vessel, or receiver.

If, on turning the vapor into the small worm in the vessel, K, and collecting the condensed portion, it be found that in the contents of this boiler no more alcohol is retained, the spent liquid is drawn off by the discharge-pipe, a fresh charge admitted from the boiler, B, and this in turn refilled from the compartment in the rectifying vessel, M. During the discharging of the liquid in boiler, A, and its refilling, the fire is slackened, by inserting the damper-plate, *w*, into the flue to cut off the draught.

The three distillations which here take place give a very strong spiritous liquor, and of a very good quality. At the end of the great worm is a water-tap, or a similar apparatus to that shown in Fig. 68. In this diagram, the end of the worm issuing from the great condensing tub is seen at *a*. *c c* is a zig-zag pipe, one end of which is immersed in a bucket of water. In the upright part of the discharging-pipe is an alcoholometer, *f*, by which the strength of the distilled product is ascertained, and *d* is a watch-glass covering the funnel-opening in the larger end of the tube, used for the purpose of seeing the bulk of the stream of liquid which flows through the worm. By this contrivance the air is prevented entering the worm, and therefore no acetic acid is produced.

Fig. 68.



The distillatory apparatus of Alègre is described in the succeeding Figs. 69 and 70. The operation in this, as will be seen, is carried on by means of the steam generated in a boiler which forms one part of the whole; and this steam, traversing the liquid to be distilled, causes the heat of the latter to rise to the boiling point, by which the spiritous vapor is expelled, and subsequently, in its route through the apparatus, rectified and condensed, as will be demonstrated after explaining the figures, to which the reader's attention is now invited.

Fig. 69 is an elevation of this distilling apparatus on the furnace side, and Fig. 70 a section made parallel to the visible part of Fig. 69. In these figures are the following parts; namely, A, the brickwork enclosing the fire, and part of the lower boiler; B, the door of the furnace; E, the lower boiler, part of which is encased in the brickwork. F is a pipe issuing from the bottom of boiler, E, furnished with a stopcock, and serving to discharge the liquid that remains after distillation, or whenever required. *g* is a pipe and stopcock, by which the proper height of liquid to be introduced into the boiler is regulated, as shown by the dotted line, *h h*, in the section. I is a tubular opening, which facilitates the cleaning of the boiler when necessary; this opening is closed by a slide plate firmly fixed in its place by bolts, or it may be secured by a screw-cap. *k* is a pipe and stopcock for ascertaining when all the alcohol has been eliminated from the liquid in the boiler, E. L is another boiler placed upon E, and which is emptied when requisite by the discharging-pipe and stopcock, M. Both these boilers are connected by the pipe, *n*, to which a stopcock is affixed. *o* is an overflow-pipe and stopcock, serving to regulate the height to which the liquor should rise in the boiler, L, as is shown in the sectional figure by the dotted line, *p*. Q is the stout plate or division between the boilers, E and L; in the middle of this bottom is an opening, on which is fixed the pipe, *r*; this pipe is open at both ends, and passes up through the liquid in the boiler, L, towards its neck; *s* is a hollow cylinder, which is inverted upon the pipe, *r*, and having its closed end uppermost. The open end rests on three small supports, fixed equidistant from the pipe, *r*, and elevated one inch above the bottom of the boiler, L; *t* is a third hollow cylinder, issuing from the bottom of the boiler, L, and rising perpendicularly till it terminates in an open end, about one inch above the closed end of the hollow cylinder, *s*, which it surrounds; *u* is a fourth hollow cylinder, placed in exactly the same position as the cylinder, *t*, and enveloping all the foregoing; the closed end being topmost, and the lower open extremity resting upon three elevations of one inch in height, and equidistant from the cylinder, *t*. A distance of half an inch is left free between its closed end and the orifice of the cylinder, *t*. *v* is a fifth hollow cylinder, which encloses the whole of the others. Its lower extremity is fixed in the bottom, Q, of the boiler, L, and its upper extremity is attached to the closed end of the cylinder, *u*. In the arrangement of these cylinders, they open alternately at the top and bottom, and by this means a passage is made for the vapor over each cylinder in succession.

x x are tubes issuing from the top of the cylinder, *v*, at an angle of about 45°, and descending to within two inches of the bottom of the boiler, L; these tubes are open at both ends, and serve as valves to close the cylinders, *v* and *u*. Three of these tubes are provided, and are fixed at the angular points of an equilateral triangle, supposed to be inscribed in the circular plane of the closed end of the cylinder, *v*; but of these only two appear, the third being in the segment of the figure which is removed.

y is a safety tube for the purpose of preventing the influx of the liquid in the boiler, L, through the open pipes, *x x*, into the cylindrical spaces in the interior of the enveloping cylinder, *v*. The upper extremity, which is funnel-shaped, is in contact with the atmosphere, and the other is in communication with the spaces in the interior of the cylinders, *v* and *u*, by passing through the closed end of the cylinder, *v*. This tube is curved, so that, at or near its middle, it dips into the liquid in the boiler. In the part ascending from this curvature to the top of the cylinder, *v*, is a bulb or enlarged portion, *z*, capable of holding about a gallon of water introduced at the funnel-opening, *y*; *a* is a stopcock, which enables the operator to know the state of the distillation in the boiler, L, and is similar to *k* in boiler, E.

c is a large tubular opening in the shoulder of the boiler, L, similar to I in the lower boiler, and affording a means by which any accumulated dirt or other matters on the bottom of the boiler is withdrawn. It is closed in the same way as I.

C is a circular basin placed upon the neck of the boiler, L, forming a refrigerator; *d*, a pipe and stopcock, which conveys heated water from the basin, C, into the lower boiler; *e* is a vase of an elliptical form, joined to the neck of the upper boiler by a bracket and rivets, as seen at *f*; *g g* are two tubes descending from the hollow cylindrical vessels enclosed in *v*, into two small vases, or circular vessels. By these pipes the phlegm condensed in the passage of the vapor over the cylinders, is returned to the lower boiler, E; the small vessels prevent any vapor passing up by these tubes—they act as a water stopcock; *h′* is a tube having two stopcocks, and branching a little below the upper stopcock; by this tube the phlegm condensed in the oval vase, *e*, is conducted at will into either of the boilers by opening the proper stopcock. *i* is a tube, rising vertically through the vase, *e*, to within one inch of the upper part of the vessel. It is closed at the top by a plate and a hollow cylinder, *k′*, whose closed end is uppermost, and rests upon *i*. The open end of the cylinder, *k′*, terminates about one inch above the bottom of the vase, *e*. The upper part of the pipe, *i*, is pierced with a number of small holes, through which the vapor passes into the vase; *l* is a tubular opening in the elliptical vase, *e*, by which it is cleaned; this opening is closed by a wooden plug; *m* is a circular basin, containing cold water, placed upon the vase, *e*, and acting as a refrigerator, and which discharges its hot water by the pipe and stopcock, *n′*.

Fig. 69.

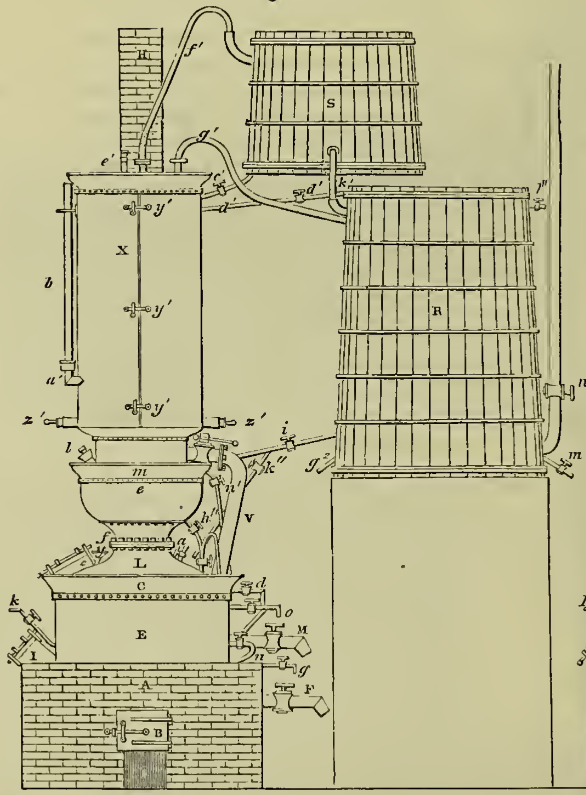
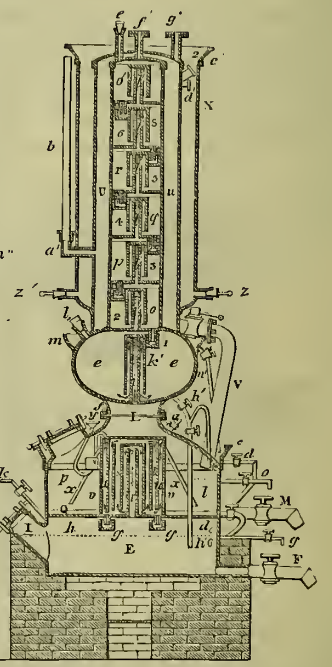


Fig. 70.



o p q r s o′ are six compartments, or diaphragm rectifiers, placed one above the other, forming by their union one cylindrical column; these diaphragms communicate with one another by means of six small tubes, *l′ l′ l′ l′ l′ l′*, placed in their centres. The tubes are arranged similarly to the tube, *i*, in the vase, *e*, the upper part of each tube being closed, and enveloped by an inverted cylinder in the form of a hat, descending to within an inch of the bottom of each diaphragm. The *l′* tubes are perforated in the upper part, to allow the vapor to pass off, and a small pipe descends alternately at either side of the column from each compartment into a small trough or dish, 1, 2, 3, 4, 5, 6, similar to those seen at *g g*, in the lower boiler, E. By these pipes the phlegm condensed in each compartment descends into that which is immediately beneath it, until it finally comes into the elliptical vase, *e*, and thence, by the double-stopcocked pipe, *h′*, it is conducted into either of the boilers, at the pleasure of the operator. Hence the condensed phlegm descending, offers no obstruction to the ascending alcoholic vapor. A long vertical hollow cylinder, U, envelopes the six compartments, *o p q r s o′*, but a space of six inches intervenes. Water is introduced into this space, and thus the cylinder, U, acts as a refrigerator to the interior column.

The hot water is discharged from the refrigerator by the large pipe and stopcock, V, into the upper boiler, whenever required. X is a cylinder reposing upon a projecting edge attached to the cylinder, U, and which serves as its base; it is made to open and shut by the latchkeys, *y′ y′ y′*. The space between this envelope and the cylinder, U, is destined to receive the grain which has germinated—malt—in order to torrefy it previous to grinding. The cover of this envelope is perforated with small holes, which give passage to the vapor evolved from the torrefying grain. *z′ z′* are two apertures made in the base of the envelope, X, by which the grain is withdrawn when properly dried. *a′* is a tube communicating with the interior of the refrigerating cylinder, U, bent upwards at right angles; at a short distance above this angle the tube is enlarged, forming a receptacle for the glass tube, *b*, serving as a gage to show the height of water in the refrigerator. *c′*, a tube with stopcock, by which the fermented liquid is conveyed into the refrigerator when one wishes to carry on the distillation by the assistance of the cylinder, U, in conjunction with the boilers; however, whether the liquid to be distilled be wine or wash, it is invariably heated here, so that it may be afterwards let down at nearly a boiling temperature into the boilers by the large tube and stopcock, V, and the smaller one, *h′*. *d′* is a pipe and stopcock, by which wine may be introduced in the same way as the wash from grain by the pipe, *c′*, when that liquid has been employed in the course of operation. *e′* is a tube by which water is allowed to enter the rectifier, composed of the six compartments, *o p q r s o′*, containing the cylindrical enclosures, *l′ l′ l′ l′ l′ l′*, for the purpose of cleaning it. *f′* is a tube, which conducts the rectified spiritous vapor from the summit of the column to the condensing worm in the superior condenser, S. *g′* is a small tube, conducting the spiritous vapor arising from the liquid in the refrigerator, U, into a small worm placed in the large condensing tun, R, collaterally with the large one. The chimney has a damper to regulate the draught from the furnace, B, which must be diminished during the charging of the apparatus.

Manner of conducting the Distillation.—When the apparatus is prepared, as seen in the figure, all the stopcocks are shut, excepting the overflow-pipes, *o* and *g*, which are left open.

The commencement of the operation is the filling of the large condensing vessel, R, with water, after which, the superior large tub, S, is filled with *wash* liquor, or wine, as the case may be. This tub contains a condensing worm, wherein the vapor arising through *f′* is partly condensed, and which is connected to the large worm in the principal condenser, R, as seen in Fig. 69, by the pipe, *k′*. After S has been replenished with liquor, the lower boiler, E, is filled through the tubular opening, I, with water, then the fire lighted, and the distillation of the water proceeded with, till the liquor in the vessel, S, acquires a temperature of about 100° Fahr. As soon as the steam from the boiling water ascends to the upper boiler, the stopcock of the tube, *c′*, connecting the vessel, S, and the refrigerating space inside the cylinder, U, is opened, and the liquid allowed to flow in until the forementioned temperature is communicated to the remaining liquor in the vessel. When this happens, the cock of *c′* is closed, and the vessel, S, replenished with more of the liquid. Both the stopcocks of the pipe, *h′*, are next opened, in order that the water condensed in the diaphragms of the rectifying column, as well as in the elliptical vase, *e*, may pass into the boilers; the stopcocks, *i*, *k″*, are at this time likewise opened to fill the refrigerating circular basins, C and *m*, attached to the upper boiler and vase, *e*. When these are full the cocks are closed, and the fire slackened by throwing on some moist small coal or wood, and inserting the damper. The object of the distillation of the water is to wash the interior of the apparatus, as well as to heat the liquor in the cylinder, U, and in the vessel, S. The stopcocks of the pipes, F, *g*, *n*, are opened in order that the water contained in both boilers, as well as in the elliptical vase, may flow out by F. During the escape of the water, the plate closing the tubular pipe, I, is withdrawn, and a besom, or mop, introduced to clean the bottom of the boiler, and force out the sedimentary matter. When the apparatus is newly erected, this distillation of water is necessary to purify the interior from rosin and other matters proceeding from the soldering, *et cetera;* but in other cases it is not requisite, unless when impurities collect in the boilers or rectifying diaphragms, or when the distillation has been suspended for some days, or after repairs; for when the distillation is carried on uninterruptedly, there is no occasion for such washing of the boilers. It is customary to fill the whole apparatus with water when not required for use, to prevent the formation of any acid which would act on the various boilers and other parts of the whole still; the water is drawn off when operations are on the point of recommencing.

The boilers being empty, the stopcocks F and *n* are closed, and the lower boiler filled with water, until it flows out by the pipe, *g*, which is at this time closed, as well as the opening, I, and the stopcocks in tube, *h′*. The fire is then hastened by withdrawing the damper; and during the time the liquid in the lower boiler is rising to 212°, the stopcocks of the pipe, V, and of the overflow pipe, *o*, are opened, and the heated alcoholic liquid in the refrigerating cylinder, U, admitted, until the boiler, L, is filled, as is indicated by the liquor flowing out through *o*. These tubes are then closed, and the tube, *c′*, opened to refill the cylinder, U, with the spiritous liquor from the vessel, S, to the proper height, as indicated by the glass gage pipe, *b′*, after which the cock of the pipe, *c′*, is shut. It is particularly necessary that the water in the large condensing vessel, R, should be thoroughly cold. This is effected by opening the stopcocks, *l″* and *n″*. By turning the stopcock, *n″*, the cold water from the reservoir, which should be erected at an elevation, and convenient to the place for the use of the apparatus, flows into the lower part of R, and the hot water is discharged through the pipe, *l″*, at the same time, by the influx of cold water beneath. Matters being thus in readiness, the vessels are charged, and while doing so the fire is briskly urged; the water of the lower boiler soon reaches ebullition, and the liberated steam, coming in contact with the bottom, Q, of the upper boiler, heats the spiritous liquor which it contains. As the steam is generated in greater abundance, it rises through the cylindrical pipe, *r*, and thence descends and ascends alternately in its course over the other successive cylinders, till it escapes by the open ends of the three diverging pipes, *x x x*, immersed in the liquid contained in the upper boiler. During this complicated course of the steam, it imparts its caloric to the surrounding liquid in the boiler, L, the content of which is readily raised to ebullition. By this means alcoholic vapor is evolved through the pipe, *i*, and after traversing the elliptical vase, the uncondensed portions ascend into the six diaphragms, *o p q r s o′*, in the rectifying column, by means of the communications, *l′ l′ l′ l′ l′ l′*. Here the rectification is principally carried on; the more aqueous portion of the vapor is condensed in each ascending compartment till it reaches the top of the column; from which it is carried off by the pipe, *f′*, into the coiled portion of the large worm, deposited in the vessel, S, where it is perfectly condensed in its course through this and the other worm in the large condenser, R, and flows in a fine stream into the appropriate backs, or spirit vats, placed below the protruding end of the worm at *m′*. The phlegm in each compartment of the steam rectifier returns by the small pipes, 6, 5, 4, 3, 2, 1, till it descends into the elliptical vase, *e*, and thence through the pipe, *h′*, into the boiler, L. As the distillation advances, larger quantities of vapor rise from the heated liquor, both in the boiler and oval vessel, *e*, as well as in the lower compartments of the rectifying column, and the condensed water from it is always descending while the distillation of the alcoholic liquor continues to afford alcoholic vapor. This is known by opening the test-cock, *a*, and applying a light to the vapor; if it inflames, it is a proof that there is still some alcohol in the liquid in the boiler, and if it does not ignite, the whole of the spirit has been eliminated; then the firing is finished, and another charge begun. The distillation of the first charge requires a period of three hours, on account of the boiler being filled with cold water; but in each succeeding operation, only two hours are required, as all the parts of the apparatus, with the water in the lower boiler, are hot.

After the whole of the alcohol has been expelled, the boiler, L, is emptied and thoroughly cleansed. This is effected by opening the tubular pipe, *c*, and the stopcocks, M and *o*, to allow the spent liquor to flow out; during this time a broom, or mop, is introduced through *c*, to detach all impurities, and force them out with the liquid through the discharging-cock, M. After the interior of the boiler has been thoroughly purified, the opening, *c*, and the stopcock, M, are shut, and the cock, V, opened, in order to allow the heated liquor from the refrigerating compartment in U, to flow in to refill the boiler. When the liquid has risen to the level of the pipe, *o*, the cock, V, is shut, and the communication between the refrigerating cylinder and the vessel, S, containing the liquid to be distilled, is opened by turning the stopcock, *c′*, and the cylinder refilled to the proper height, as indicated by the gage pipe, *b′*. The connecting-pipe between the vase, *e*, and the under boiler, is opened by turning the cock, *h′*, and closing the lower one with which this pipe is supplied, in order that the phlegm collected in the vase during the distillation of the preceding charge may flow into the lower boiler, whose overflow pipe, *g*, should be opened to indicate when it is full. If this phlegm be not sufficient to fill the lower boiler, the remaining quantity of liquid is allowed to flow in from the refrigerating basin, C, attached to the upper boiler, by opening the stopcock, *d*. As soon as the liquid flows out through the pipe, *g*, the stopcock of this, as well as the cock of the pipe, *d*, is closed, and the fire stirred. Shortly afterwards, when the steam from the lower boiler rises through the apparatus, the stopcock of the pipe, *n′*, is opened, that the hot water contained in the refrigerator, *m*, may descend to that attached to the boiler, L. After the whole of the water is run down, the tap, *n′*, is shut, and *i* and *k″* opened, to replenish both the refrigerating basins with cold water from the large condensing vessel, R. The second firing is about this time in progress, the liquid in the boiler is deprived of its alcohol in the manner as before explained, and the distillation of the charge is completed in about two hours. A similar mode of operation to that described takes place at each charge, irrespective of the alcoholic liquor submitted to distillation.

It will not be out of place here to offer a few words explanatory of the mode of torrefying the malt in the space between the cylinder, U, and the outer envelope, or casing, X.

The sprouted grain is introduced through the circular opening in the top, between the envelope, X, and the cylinder, U. The heat from the cylinder, U, is by this means rendered available for torrefying the grain; and this is a matter of great economy in a distillery, as by it the erection of a kiln, and the consumption of fuel required to heat it, are dispensed with. When the grain has dried to the proper degree, it is removed through the openings, *z′ z′*, and replaced by more moist malted grain, to undergo the same process.

Mr. **Miller**, of Glasgow, secured a patent for a new still for the distillation of spiritous liquors, and the fermented wash of malt and grain. The novelty of this still lies in the employment of evaporating cones, having open spiral channels winding round their exterior. In other respects the still embodies the main features of all the principal distilling arrangements of the time, already described; namely, that of returning the products of the first condensation, which contain an excess of water, to the body of the apparatus for a further rectification.

Fig. 71 shows the principal parts of the still and worm; Fig. 72, a sectional view of the cone, which embodies the improvements. A is the body of the still or boiler, which is of ordinary construction. The head of the still, A′ A′ A′, consists of three cones, placed concentrically, B, C, D, but a small distance apart. Both surfaces of the cones, B and D, are plain, but round the exterior of the cone, C, an open spiral channel, X, winds from the top to the base. The position which this part occupies may be better understood from the detached view of the cones in Fig. 72, where X X shows the channel, and C the cone. A pipe, E, leads from the annular space between C and D to the wash-heater, F, which consists of a vessel filled with a number of small parallel pipes, and communicating with a low-wine condenser, G, which is placed in the upper part of the worm tub. The wash is supplied to the vessel, F, by a wash-charger reaching from the backs, and communicating with the vessel, F, at M; this, however, is not shown in the figure. I is a pipe which leads from the top of the outer cone, B, to the spirit condenser, K, which consists of a cylindrical case, inclined towards the still, and containing a number of pipes laid longitudinally, through which the gaseous products pass, it is filled with water supplied by a pipe not seen in the figure; the heated water is discharged through the pipe, Q. The pipe, K′, issues from the end of the spirit condenser, and enters the refrigerator, where it is united to the worm, L, placed in the bottom of the tub, W. O and *i* connect the condensing pipes in the vessels, K, F, and low-wine condensing worm, G, with the outer part of the cone, C; and the pipe, H, serves as a communication between the top of the wash-heater, F, and the body of the still, for the purpose of charging the latter.

Fig. 71.

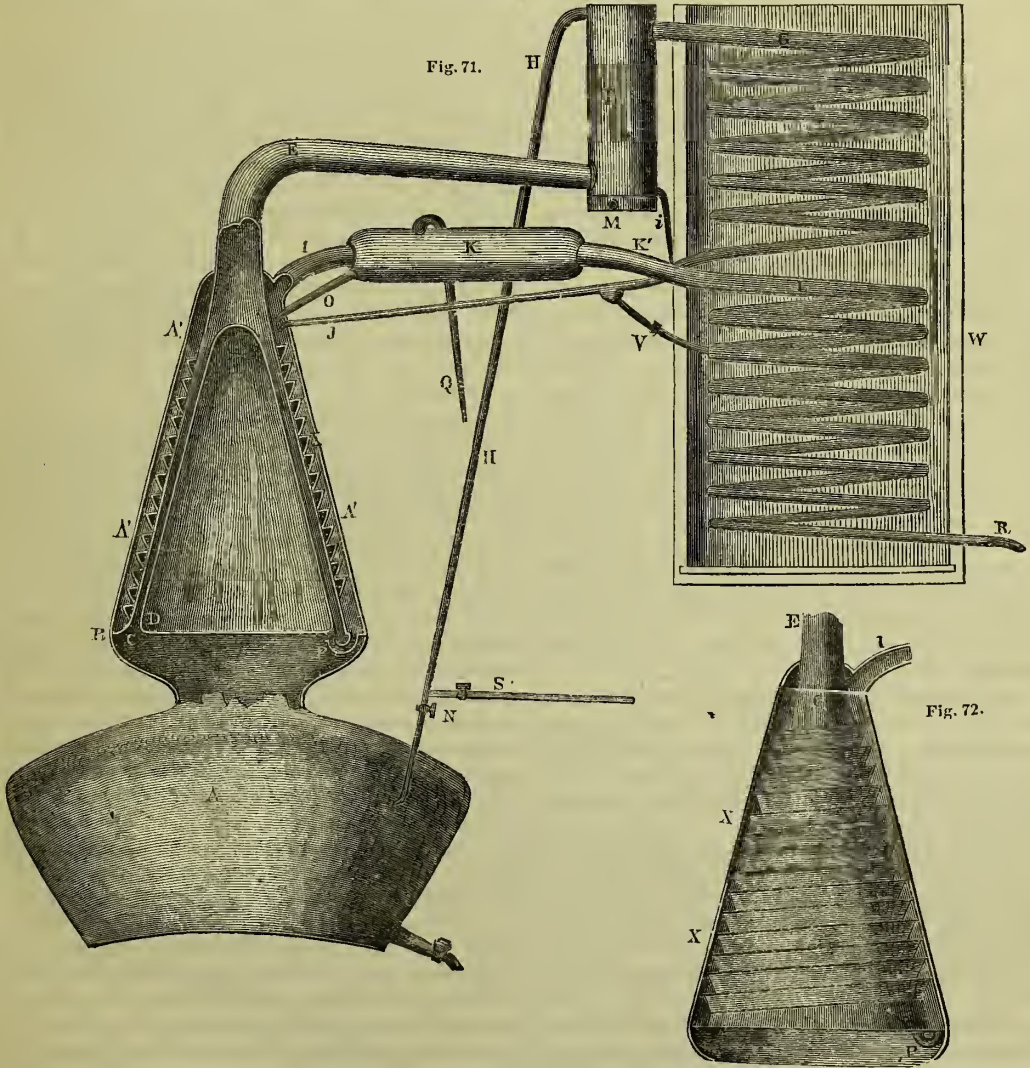


Fig. 72.

The following is the mode of working:—A quantity of wash is run into the still, A—which is supposed to be placed over an ordinary furnace—from the wash-heater, F, through the pipe, H, to the height of say three or four inches. As the wash boils, the vapor arising from it ascends the space in the still head, A′A′A′, between the cones, C and D, and through the pipe, E, into the wash-heater, F; part of the vapor is here condensed, and the remainder passes off into the low-wine condenser, G. The latent heat of the vapor is evolved in its passage through the vessel, F, and serves to raise the temperature of the liquid contained in it, after a while, to the boiling point; the condensed liquor in F, as also that which is formed in G, returns through the pipes, *i*, J, into the top of the space, B and C, in the still head, and flows into the channel, X, where it is reheated in its descent through this compartment to the base of the cone, by the simultaneous ascending vapor between C and D, and the portion thus evaporated flows off through the pipe, I, to the spirit condenser, K. That portion of the liquid which is not converted into vapor, is ejected from the cone, and received into the boiler through a pipe, P, to undergo another distillation.

In the spirit condenser, K, a further rectification takes place; all the finer parts of the spirit passing off through the pipe, K′, into the worm, L, where they are condensed and discharged through R into the spirit-back, while the coarser products that are condensed return through the pipe, O, into the canal, X, for a further purification. Whatever be the quantity of wash which is introduced at first into the still, no more should be allowed to enter till the whole of its alcohol is expelled. For this end the supply pipe, H, is furnished with a stopcock, N, and a branching pipe, S, for the purpose of drawing off any excess of wash into a tank appropriated to that purpose. Towards the end of the distillation, the weak faints may be run off from J, by means of a branch pipe, V, that enters the large condensing worm.

The Bushmills.—Before concluding the article on malt whisky, a short account of the Bushmills may prove interesting, as this spirit is said by many to claim pre-eminence over all others, in the same manner that genuine hollands is considered superior to any gins made in this country.

Bushmills is a small but very thriving market town in Ireland, situated upon the river Busk, or Bush, and about a mile and a half from the Giant's Causeway.

The town has long been celebrated for its superior malt whisky, there being two distilleries, one of which has been established about thirty, the other twenty, years.

In the oldest of these distilleries the spirit is made exclusively from malt, which is prepared in the ordinary way, excepting that peat is used in drying it. The quantity of malt wetted for each brewing is eighty bushels, from which only one mash is prepared for fermentation, the after-washings being retained, as usual, for exhausting fresh quantities of malt. In preparing the first mash, about eighteen to twenty gallons of water are used to each bushel of malt. Only as much water or small worts is let on as will wet throughout the whole of the malt; the temperature is 146° Fahr., and in fifteen minutes afterwards, the remaining quantity is run on at a heat of 155° to 160°.

After drawing off the first mash, nine hundred gallons of water are let down into the grist at a temperature of 170° to 175°, and after mashing from three-quarters to one hour and a quarter, the wort is let into the under-back, and pumped into the coppers. Nine hundred gallons more are used in the third mash, the temperature being 180° Fahr.; both these liquors are used in making the first mash on the next day's brewing, and on account of the density of the small worts, the malt used is from sixty-five to seventy bushels.

The density of the first mash, when let into the fermenting tun, is fifty pounds to the barrel as usual. None but the best of barm is employed in the fermentation; the quantity is one per cent. of the wort, one-half of which is added at the commencement, and the other when attenuation has reached 30 or 35. Attenuation is completed usually in forty-eight hours, though in variable weather a longer time is required; the quality of the malt also affects the quickness of the decomposition, but the chief cause of a good or bad fermentation is the yeast; the fermented worts are reduced in gravity to that of water, and frequently below this. The mash stills at the Bushmills factory are of the old description, and the manager states they are the best for making fine spirit, an assertion with which many will coincide.

The average yield in this establishment is from fourteen to sixteen gallons per quarter of eight bushels, but there is always a variation above or under these figures, according to the quality of the grist. The best spirit is made always in dry weather.

Potteen Whisky.—This far-famed spirit was some time ago more extensively manufactured throughout the kingdom than at present. It seems to be more than ever prized on account of its scarcity, and it bears a high price, particularly the Scotch and Irish. The singular flavor of the Irish produce is supposed to be caused by using turf for the exsiccation of the malt. DONOVAN relates that a few years back, being on a journey amongst the mountains in the most Northern parts of Ireland, he learned there was a potteen distillery at work; he despatched an emissary well known to the distiller, to procure him admission, which was granted. It was a place renowned for producing good whisky. The distillery was a small thatched cabin; there was a large turf fire kindled at one end, and confined by a semicircle of large stones, upon which a forty gallon tin vessel, serving the twofold purpose of a water-heater and a still body, was resting. An orifice in the roof, immediately over the fire, served as a chimney for the escape of the smoke after it had traversed the apartment. The fumes of the burning turf were so acrimonious as to produce a smarting of the eyes, which annoyance was got rid of by sitting down, owing to the fumes occupying the upper stratum only of the air; they consisted principally of pyroligneous acid.

The mash tun was a cask hooped with wood, at the under part of which, next the chimb, was an opening plugged with tow. This vessel had no false bottom; in place of it young heath was strewn, and over this a stratum of oat-husks. Here the mash of hot water and ground malt was occasionally mixed up for two hours; after which time the vent at the bottom was opened, and the worts were allowed to filter through the layers of oat-husks and heath. Mashing with hot water on the same grains was then repeated, and the worts were again withdrawn. The two worts being mixed in another cask, some yeast was added, and the fermentation allowed to proceed until it fell spontaneously, which happened in about three days. It was now ready for distillation, and was transferred into the tin boiler, which was capable of distilling a charge of forty gallons. A piece of soap, weighing about two ounces, was then thrown in to prevent its running foul; and the head, apparently a large tin pot with a tube in its side, was inverted upon the rim of the body, and luted with a paste made of oatmeal and water. The lateral tube was then luted into the worm, which was of copper of an inch and a half bore, coiled in a barrel for a flake-stand. The tail of the worm, where it emerged from the barrel, was calked with tow. The wash speedily came to a boil, and then water was thrown on the fire; for at this period is the chief danger of boiling over. The spirit almost immediately distilled; it was perfectly clear; and by its bead, this first running was inferred to be proof. Its flavor was really excellent; and it might well have passed for a spirit three months old. As soon as the upper stratum of water in the flake-stand became warm, a large pailful of cold water from an adjoining stream was dashed in with sufficient force to make the hot water run over, it being lighter; and this cooling process was continually resorted to. In this way, the singlings were drawn off in about two hours, and those from four distillations made one charge of the still to produce the potteen.

The malt was prepared by enclosing the barley in a sack, and soaking it for some time in bog water, which is deemed the best; then withdrawing and draining it for some time, after which it is made to germinate in the ordinary way. When it had grown sufficiently, it was conveyed in a sack to the kiln, along with some sacks of raw corn, for the purpose of concealment. The raw corn was spread out on the kiln, but during the night, when the kiln-owner had retired, the raw corn was removed, the malt spread, desiccated, and replaced by the raw grain before day. The owner of the corn drying on a kiln, sits up all night to watch it. In this way discovery was eluded, and the malting terminated. Besides the much-valued flavor of potteen, it had derived a part of its character owing to its being distilled entirely from malt. Now, however, about one-fourth of raw corn is generally added. From a bushel of this mixed grist, the potteen-maker obtains a gallon of spirit, of what is called three-to-one; or three glasses of spirit mixed with one glass of water afford proof spirit. This is, according to calculation, much below the produce that ought to be obtained.

The body of the still cost one pound, its head four shillings, the worm cost twenty-five shillings, the mash tun and flake-stand, twelve shillings; three pounds was, therefore, the value of the whole distillery. It is purposely conducted in this economical plan, as it holds out no inducement to informers or Excisemen. Sometimes they have been constructed on an extensive scale. It is very doubtful whether the aroma depends on the turf smoke, for it is stated that the spirit has the same taste and odor when coal is burned under the kiln. It is possible that the turf smoke may be absorbed by the spirit, for it is well known that there is a period of the alcoholic fermentation at which odors are apt to be retained. The peculiar flavor must certainly arise either from the turf or the bog water in which the malt is steeped. When dried in the kiln after steeping, the heat is often sufficient to char the bog extract remaining in the malt; consequently, this would communicate an agreeable smoky aroma to the spirit.

MOREWOOD gives the annexed interesting details on the subject of illicit distillation:—The spirit distilled from pure malt is considered superior to that made from a mixture of malt and raw grain. To assign a reason for this, would require an analysis and report of particulars of the process of malting; but it may be sufficient to observe, that the effects of the malting process are similar to those the grain undergoes in the course of vegetation, when sown in the earth. Illicit distillers, as if aware of the value of this metamorphosis, almost invariably use malted grain. From a want of scientific knowledge and proper utensils, they conduct their business in a different manner from that pursued by licensed traders. In preparing the malt, the sacks of barley are generally steeped in bog-holes or other places, where they remain forty-eight hours, or until completely saturated with the water. They are then drawn out and drained for ten or twelve hours. After this the grain is spread out upon the floor in a thick layer, and remains so till it begins to chip or germinate; it is turned occasionally, until all appears alike sprouted. It is afterwards spread by degrees, till such time as the buds show three points, and when these points have grown half way down the grains, by means of a regular heat, the particles are semi-transparent. At this stage it is spread thicker on the floor, and brought to a heat easily perceptible to the hand, then thrown into a round heap, and suffered to remain in that state for twenty-four hours, or longer; the latter is termed the rot or withering heap. It is then carried to the kiln and dried by turf; the kiln-head on which it is dried is covered with decayed straw, over which, if convenient, is placed hair-cloth or matting. The period of drying a kiln-head or crop, as it is termed, is commonly twenty-four hours, when directed by a person of experience. The grain, while on the kiln, is carefully turned by the hand, to expose every particle to the same heat, and to prepare it for coarse grinding. It is next taken to the still-house, which is usually a hovel or excavation near a running stream, or where there is a full supply of water. The quantity of malt to be brewed is commonly from sixteen to seventeen stones; after being bruised or mashed in the ordinary way, it is covered in the kiln with a lid or sacks, and suffered to repose for three or four hours. The worts are then drawn off, and cooled to a temperature regulated by the finger, no instrument being used for that purpose, and commonly to the same degree as that which is observed in regular distilleries; they are next put into a pipe or puncheon, with about a gallon of yeast; in an hour or two after the barm is added, fermentation begins, and in twenty-four hours afterwards, the attenuation is considered complete. Sometimes two brewings, after undergoing the fermenting process for about eighteen hours, are considered fit for the still; and in the ordinary course of working, a brewing is made every morning. The quantity of pure spirit drawn from these two brewings, is usually two hundred and twenty-three gallons, of one-to-two, or two-to-five; or, in other words, the spirit is of such a strength that it will bear one gallon of water to about two gallons of spirit, or two gallons of water to five of spirit, to bring it to proof. The usual strength at which illicit spirit is made, is from four to six over proof on Sykes' hydrometer; but sometimes it is as much as eight per cent., and in many cases it has been sold at a strength of thirty over proof.

In making the malt, and in the mode of distilling, the flavor is altogether formed; no machinery is employed in the still to keep the liquid from empyreuma.

In distilling the wash, the strong low-wines are separated from the weak, the latter being thrown back into the still with the succeeding charge of wash; a similar practice is observed in making spirit, the faints being put into the still with the next charge of low-wines. Thus the spirit is preserved pure and clear, nothing whatever being used in the distillation but a small quantity of soap thrown into the still with the pot-ale or refuse, to neutralize or keep down the yeast, as they term it, which would otherwise cause the run of the low-wines to become colored like the wash, or to get foul. It is a mistaken notion to suppose that soap is used only by the larger distillers, since it is considered an indispensable article by every person who understands the mode of working a still on the old system.

The spirit of these illicit stills has been long a favorite beverage in Ireland, being from malt without adulteration, and possessing a flavor which habit has rendered most agreeable. This, combined with the high duties on legally-distilled spirit, and the want of a ready market for the disposal of the grain of remote and mountainous districts, induced the people to embark in this contraband traffic to an extent which was not only injurious to the agriculture and revenue of the country, but to the morals and peaceful habits of the community. To such an extent was it carried, that in 1806, out of eleven million four hundred thousand and thirty gallons, the computed consumption of spirit in Ireland in that year, three million eight hundred thousand gallons were allowed to be the produce of illicit manufacturers, and in 1811, 1812, and 1813, there were no less than nineteen thousand and sixty-seven illicit distilleries destroyed by the revenue and military.

To put down this unlawful trade, various enactments were passed by the legislature, among which that of fining the townlands on which any portion of a still, wash, low-wines, or other materials for distillation were found, was not the least oppressive. The annual average of fines levied for seven years under the act for the suppression of this evil, amounted to fifty thousand nine hundred and eighty-nine pounds for all Ireland, while in one county alone, the sum paid in 1806, was two thousand six hundred and twenty pounds; in 1807, two thousand seven hundred and fifty; and in 1814, eighteen thousand one hundred and twenty-five. How could it be expected to be otherwise, when it was proved before the parliamentary commissioners, that many men were found to declare they had never done a day's work in their lives except at illicit distillation, and that they knew nothing else by which they could gain a livelihood?

Many interesting and curious facts might be related of the extraordinary contrivances of the people to evade the law and prevent detection, such as the artful construction of distilleries on the boundaries of townlands, in the caverns of mountains, on islands in lakes, on boats in rivers; of carrying away and secreting revenue officers for weeks together to prevent their giving testimony, the romantic manner of their treatment while in confinement, and the various other schemes and devices to defeat the intentions of the government.

Among these, MOREWOOD narrates the instance of a person who had constructed a distillery so artfully, that it eluded the vigilance of the most expert officers of Excise, though they knew of its existence in the neighborhood. A determined functionary of this staff resolved to find it out at all hazards, and on one moonlight night, alone, he followed a horse led by a peasant, having a sack across the back of the animal, which, he suspected, contained materials for this mysterious manufactory. When the horse had arrived at a certain place, the sack was removed from his back, and suddenly disappeared. The officer made his observations, returned to his residence, and having procured military assistance, repaired to the place where the horse had been unloaded. All was silent, the moon shone bright, the ground was unmarked by any peculiar appearance, and he was almost inclined, as well as those who accompanied him, to think that he had labored under a delusion. Perceiving, however, some brambles loosely scattered about the place, he proceeded to examine more minutely, and, on their removal, discovered some loose sods, under which was found a trap-door leading to a small cavern, at the bottom of which was a complete distillery at full work, supplied by a subterraneous stream, and the smoke conveyed from it through the windings of a tube that was made to communicate with the funnel of the chimney of the distiller's dwelling-house, situated at a considerable distance.

Another distillery has been known to be worked on the site of, and in conjunction with, a lime-kiln, which, from the kiln being continually in operation, kept the other for years without detection. So cunningly were some of those still-houses situated, and so artfully constructed, that the smoke proceeding from them was made to issue as if from burning heath or sods of peat ignited for manure. Their position was, for the most part, either on a commanding eminence, in the centre of a bog, or in a well-secured stronghold, but always calculated to prevent the identity of townland or proprietorship; while the portability and easy removal of the apparatus rendered the discovery and seizure of those stills difficult and hazardous. On the approach of a stranger, an alarm was given, either by deputing a messenger or sounding a horn, while the machinery was removed and the pot-ale always destroyed, or conveyed into receptacles under ground, prepared for such exigencies. Thus the still-hunter was often disappointed of his expected prize, the poor distiller put to the loss of many a brewing, and the Excise officer rendered the object of the hatred and vindictive feeling of the unreflecting peasantry.

The fines on townlands having been abolished, it was found necessary to adopt some other measure to put down illicit distillation. Recourse was therefore had to a revenue police, the Excise officers having too much other business to attend to, and the difficulty and expense of procuring regular military assistance being almost insurmountable. Accordingly, a revenue police was established in 1822, and was gradually augmented, in proportion to the exigency of the service. In 1826 this force amounted to thirty-two parties; in January, 1833, to fifty-seven parties; and in 1838, to seventy parties, amounting, including officers and men, to upwards of twelve hundred persons. They were distributed through those parts of the country in which prohibited distillation most prevailed; and though their exertions have been very great, yet they have but partially suppressed the evil. Their services will be best appreciated by an enumeration of the detections made by them in four successive years .—

	Stills.	Malt. Bushels.	Distilleries.	Worts. Gallons.	Spirits seized. Gallons.
1830, ...	804 ..	25,136 ..	1,788 ..	122,263 ..	624
1831, ...	123 ..	24,901 ..	1,479 ..	106,908 ..	353
1832, ...	974 ..	47,683 ..	2,299 ..	203,472 ..	1150
1833, ...	1537 ..	71,782 ..	3,300 .:	320,813 ..	6944

Of the many plans which have been laid to obstruct the revenue officers in the discharge of their duty, the following is not the least deserving of notice :—On the approach of the assizes of 1803, when many were about to be prosecuted for illicitly distilling, an officer, stationed at Dunfanaghy, in the county of Donegal, who was to support the informations, was suddenly seized, blindfolded, and carried away by a body of men in disguise, and brought to the island of Arran, on the Western coast. Thence he was conveyed to the islands of Goal, Innismay, *et cetera*, where he was closely confined, often threatened with the loss of life, and was even obliged, by way of humiliation for his active services, to assist in the working of an illicit still; while, like another Tantalus, the cup of pleasure was held to his parched lips, without the liberty of gratifying his thirsty desires. At the end of thirteen days, when the necessity for his confinement had ceased, he was again blindfolded, taken from the island, and sent a considerable distance into the interior of the country, where the mask was removed from his face, and he was allowed, in the solitude of night, to make his way to his disconsolate family, who, all the time, had looked upon his restoration as hopeless.

Another officer, on a similar occasion, was hurried from his bed, put into a sack, thrown across the back of a horse, and in this manner was conducted to the margin of a lake, where, in his own hearing, a consultation was held as to whether he should be drowned, by tying a stone to the sack and committing it to the deep, or be put to a more lingering and torturing death. In this awful state of suspense he was removed to a mountainous part of the country, where he was subjected to every kind of insult and privation, continually menaced with death in every shape of barbarity, led out at night as if about to be executed, and reconducted to his solitary habitation, anticipating a renewal of further cruelties. In this state he was retained for a considerable time, till the judge who presided at the assizes, during the trial of some persons for illicitly distilling, suspecting the parties as being accessary to this outrage, told them, that if the officer who had been taken away was not immediately liberated, he would pass such a sentence on them as would for ever put it out of their power to commit such another offence, and gave them but twenty-four hours for his restoration. This had the desired effect: the unfortunate man was again put into a sack, and restored to his family in the same manner as that in which he had been carried away.—*Morewood.*

Whisky is generally made in the United States from Indian corn; and in Cincinnati, where this grain abounds, there is so large a quantity of alcohol and whisky manufactured as to supply the Western and Southern markets.

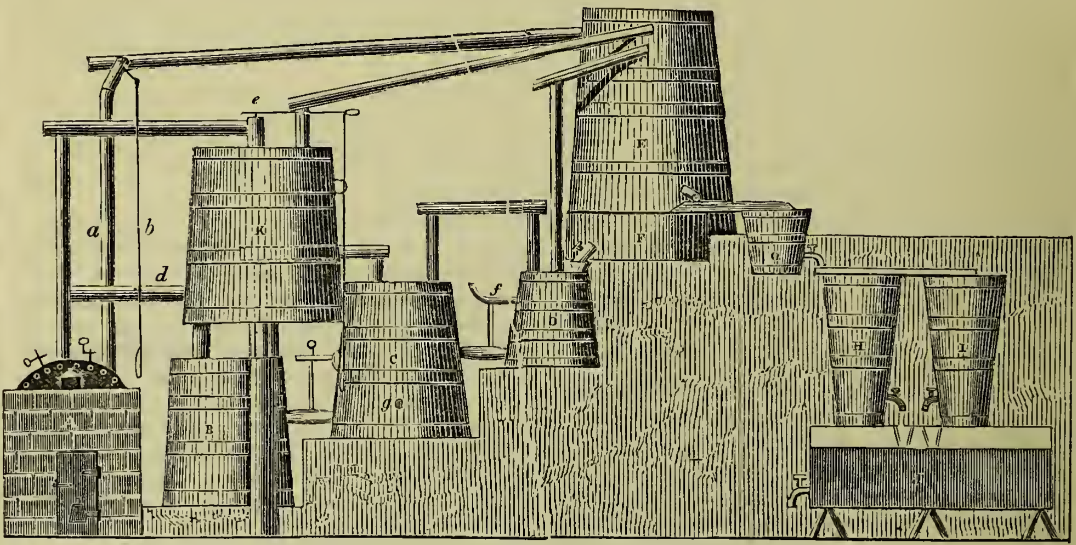
The opposition given of late by the temperance societies to intoxication, has diminished the consumption of spiritous liquors very much in the United States. Some States are prohibited by law from either manufacturing or vending ardent spirit of any kind, and they are using their utmost endeavors to have the same law passed by the legislatures of other States.

Numbers of distilleries are now at work in Canada; like those of their neighbors, they are mostly of wood, and worked by steam. In Pittsburg, and other parts of the United States, the whisky is purified by filtering it through charcoal coarsely ground. Seven miles from the city of Toronto is a large distillery, the annexed drawing and description of which—Fig. 73—are taken from Morewood.

A is the brickwork, in which the iron boiler, with a cylindrical flue running through the centre, is partly enclosed. B and C are the first and second wooden stills, of the same size, being four feet eight inches at bottom, and four feet six inches at top, with an altitude of six feet; D is the doubling or low-wines' still, two feet ten inches at bottom, and two feet four inches at top, the height being three feet nine inches: E is the worm-tub, six feet at bottom, five feet at top, and nine feet high, supplied by a copious stream of water; F the low-wines' and faints' receiver: G is the recipient for the spirit previous to passing through the rectifiers or filtering vessels, H, I, and is two feet at bottom, two feet four inches at top, by two feet in height. The top diameter of H and I is three feet, and the bottom two feet, the altitude being five feet; they are filled with charcoal and other material, through which the liquor gradually descends in a limpid, gently-flowing current into J, the final receiver, or store cask. K is a tank or large vessel for holding warm water for distilling purposes, supplied from the top of the worm tub, the heat of which is supported by steam from the tube, *c*, connected with the boiler, and having a stopcock for regulation at *e*. The tank is a reservoir for supplying the mash tubs with water, of which, in the establishment, there are fourteen, each measuring three feet four inches by three feet six inches in diameter, ranged on a loft above the stills, in such a manner that, after the worts have undergone fermentation in these tubs, they are let down by a leader or trough into the second still, C, at *g*. When the first charge is worked off, the remainder is let into the first still, and the second still is charged from the mash-keeve. To facilitate the operation, there are pipes with proper stopcocks from still to still, such as that at *f*; and it will be perceived that the whole process of distillation is effected by means of steam admitted through the tube, *d*, projecting from the main upright pipe of the boiler into the first still, B, and so proceeding by other pipes through the other stills. The tubes which convey the steam into the stills descend to nearly three or four inches from the bottom.

All the vessels and pipes, as well as the stills, are made of pine; the pipes are nine inches square, with a bore of two and a half inches in diameter. The steam-boiler is seven feet deep, the height of which, at the fire place, is eight feet, and it is supplied by water from the worm-tub by the pipe, *a*, regulated by a stopcock or ball of lead which is worked by the cord, *b*. It is not necessary to describe the other vessels of this arrangement, as they are similar to those employed in the distilleries of Scotland and Ireland. The greatest disadvantage attending it, is the liability of the timber becoming soon unserviceable when the operations are discontinued for any time; but in a country like Canada, where wood is so plentiful, this inconvenience is readily repaired.

Fig. 73.



The wash is usually made from rye, wheat, or Indian corn, with a mixture of one-twentieth part of barley malt, or one pound to the bushel of mixed grain; many use a larger quantity. This is ground or crushed in a mill, and then mashed with water, at a heat ranging between 158° and 162°; others work at a temperature so high as 180° and 190° Fahr., but this is uncommon. When mashed, a cover is immediately put on the tubs, or keeves, in order to preserve the heat as much as possible. The mash is then permitted to remain, with an occasional agitation by the rakes for about two hours, until the menstruum acquires its proper sweetness; at this stage, cold water is added to reduce the heat to 60° or 64°, but mostly to 70° or 74°, when yeast is added. This yeast is home made, in country places in particular, but in the towns it is usually procured from brewers. The tubs or keeves are again covered and allowed to repose until completely fermented, when the distilling commences. The grains and all are put into the still. Brewing and distilling are generally carried on in the Canadas from October till May.

No duty is charged on malt in the Canadas, and the distillers have, therefore, every encouragement to make use of it in what proportion they may deem necessary for the production of a good and palatable spirit; the ale made from it is celebrated in the West Indies.

RECTIFICATION OF SPIRIT.—On recapitulating the steps through which the production of spirit has been traced, it will be seen that at first the grain—sometimes mixed with malt—is crushed in order to allow hot water to act more readily upon its mealy ingredients; next, the mashing takes place and worts result; then the fermentation of the worts commences, whereby the saccharine principle is resolved into alcohol; finally, this alcohol is, by successive distillations, separated from its greater portion of water, and *plain British spirit* is obtained. Alcohol, so highly prized by chemists, the various forms of spiritous liquors known as hollands, whisky, gin, British brandy, and rum, and the cordials under the name of peppermint, cloves, aniseed, *et cetera*, are produced by the rectifier, from plain spirit purchased from the distiller; consequently, the two branches are perfectly distinct. British spirit is but little known in the form in which it leaves the distillery, because it receives from the rectifier the exclusive property by which it is rendered a household word. One of the most extensive and elegant rectifying distilleries is that of Messrs. CHILD and SON, in London, and from all accounts the resources of modern science are there brought to bear on this particular branch of manufacture with tact and discrimination.

The manufacturer of whisky, or any of the other alcoholic liquors, rarely purifies the products, but disposes of them to the rectifying distiller, whose business it is to remove from them any contaminations which render them disagreeable or highly injurious. If, however, the fabricator conducts this operation as well as the original preparation from the grain, a distinct part of his premises is allotted to the work, according to legal enactments, and a peculiar process followed, which will be here considered.

All spiritous liquors are identical, when the extraneous bodies from which such liquors are obtained have been removed, with this exception, that a variable amount of water is present in them; they are more or less concentrated solutions of *alcohol*, whose properties have been fully given; thus, the alcohol from wine, rum, malt, potatoes, carrots, beets, grasses, and various other sources, is the same in quality, provided all the other solid and liquid impurities be removed. A single distillation of the spiritous portions of those liquids will not effect their purification, and where volatile oils are present, distillation merely, how often soever repeated, will not separate them, for these volatile impurities pass over during distillation; hence, the spirit procured from wines by simple distillation will have their peculiar flavor; beer, when distilled, will, for the same reason, yield alcohol possessing the abominable taste of the yeast; malt spirit will have the disagreeable qualities of faints from the presence of an oil of an acrid bad taste; and potato spirit the physical characteristics of fusel oil, or oil of potatoes. Thus, the disagreeableness or fragrancy of distilled products is, as in the case of malt and potato spirit, due to the presence of an essential oil, derived from the source of the alcoholic liquid. The chief object of the distiller in rectifying spirit is the removal of these oily bodies in order to procure a pure alcohol, from which, by the aid of other ingredients, he can fabricate liquors imitating those more costly products which are formed naturally, such as the better varieties of brandy, gin, whisky, and all the other kinds of liquors and cordials which are in daily request as favorite beverages with the community.

Caustic potassa—under the name of grey salts—or soda, is added to unite with the oil; pearl-ash—white salts—is employed with the view of combining with the water, as was mentioned under the formation of absolute alcohol in the commencement of this article, as well as to take up the fatty or oily impurities. The alkali combines with the oil, giving a soap which remains in the still, while the spirit passes off divested of its impurities. It has been ascertained, that when carbonated alkali is used, the distillate contains some of the salt, as it affects litmus and turmeric papers—hence this method cannot always be followed. Every rectifying distiller in the kingdom fabricates cognacs, genevas, usquebaughs, *et cetera*, from the disagreeable low-wines of the malt distiller, or from the foul potato or carrot spirit of foreign manufacturers.

All of these spirits, as they come from the first distillation of the respective mashes, are called low wines or *singlings*, and are charged with oils, and unfit for any use while in that state. When they are redistilled, the first portion which comes over is much purer, and contains less water than the singlings; this is called the *foreshot*. So much of this spirit as can be produced without the smell of faints, is retained as whisky, and the remaining portion is diluted and submitted to further distillation.

The strength of whisky, as sent out from the manufactory, is generally about twenty-five per cent. over hydrometer proof, on Dicas' scale. On a further distillation of this whisky, a spirit is obtained which marks about forty-six per cent. over proof, and is about the strength of spirit of wine in general; of this, about eighty gallons are obtained from one hundred gallons of ordinary whisky, of twenty-five per cent. over proof. A further distillation affords a liquid of spec. grav. 0·820, which is the strongest spirit that can be obtained by mere distillation.

When various compounds, such as chloride of calcium, caustic lime, sulphate of soda, or acetate of potassa, have been employed, either for the purpose of uniting with water or oily matter in the liquors, portions of these bodies are, according to the statements of DUBUE, invariably found in the distillate. The same authority states, that when spirit was distilled over calcined alum, the condensed liquid reddened litmus paper, but when sulphuric acid was added in small quantity to the spirit, not exceeding thirty-eight degrees of the areometer, the product which came over was found to be quite pure. Alumina, or aluminous clay, well washed and dried, was found capable of abstracting small quantities of water from spirit, and no portion of it passed over into the receiver.

Charcoal is a means by which the disagreeable flavor of spiritous liquors is removed. It has been made the subject of investigation by several chemists, among whom, LÖWITZ ascertained that, by distilling common malt spirit over charcoal, its peculiar bad smell was removed; this is also effected by merely agitating the two together. He performed ten experiments, with one pound of common spirit for each operation, and a variable quantity of charcoal, from half a drachm to five ounces, with the following results:—

Half a drachm of charcoal scarcely altered the smell, and the liquor did not clear for six months.

One drachm of the charcoal had no better effect in removing the bad flavor and odor; but cleared it in four months.

Two drachms cleared the spirit in one month.

Four drachms removed the smell in a very sensible degree, and the spirit became clear in one month.

One ounce of the charcoal completely freed the spirit from the bad smell, and clarified it in a fortnight.

An ounce and a half cleared it in eight days; three ounces in five days; four ounces in twenty-four hours; and five ounces in two hours.

From the experiments of HAHNEMAN and KELS, it would appear that the use of charcoal in purifying spirit confers a peculiar fiery taste, whether the alcoholic liquor be drawn off by distillation, or by agitating the mixture, then allowing the charcoal to subside, and afterwards decanting the clear liquid; its use is therefore objectionable.

KUNKEL was the first chemist who made the essential oils, contained in spirit, the object of research. His method of rectification was to dilute largely with water and distil, by which the product was much improved in flavor.

Wood-ashes had, for a long time, been almost in general use in the rectification of spiritous liquors; their beneficial effects are due to the amount of alkali they contain, which enters into combination with the small quantity of acid formed in the spirit, as well as with the oily matters. It would appear that filtration through hydrate of lime has the effect of removing some of the essential oils from spirit; the practice had been followed in France, particularly among those who carried on an illicit trade by adding an odoriferous oil to their brandies, and then entering them at the Customs as perfumes.

The fragrant principle was removed, subsequently, by diluting with water, and filtering through lime, slaked in the air, which had the effect of separating the oil, provided it had not been present in great excess.

ZEIZE affirms that agitation with a small quantity of hypochlorite of lime has the effect of destroying the essential oil, and that the spirit, after distillation from the lime compound, resembles brandy in flavor; most likely a small quantity of chloroform imparts the bouquet. Milk, according to the views of M. CADET DE VAUX, has the peculiar property of removing the bad flavor from the spirit obtained from the wines of various mellow and sweet fruits. This is effected by one or two distillations with milk, and the spirits obtained are almost identical, and much improved, notwithstanding that they were procured from quite different sources.

The rectifying distiller now only considers the removal of the oil, since the improved apparatus affords an alcohol of any strength which is required in all ordinary cases. The proportion of salts employed for removing the oil from the crude proof spirit of the large wash distillers, is about

4 lbs. grey salts, and
4 lbs. white salts,

to every seven hundred gallons of the ordinary product. Where the distiller infers that an unusual quantity of the foul oil is present, the proportion of salt is increased, and sulphuric acid is also added in order to ameliorate the flavor of the spirit by giving rise to an ether. The salts are dissolved in about two gallons of liquid, and if the commercial article be used, it is found necessary to remove the sedimentary impurities by filtration. This alkaline solution is mixed with the liquid, and the distillation commenced. If the ordinary common still be employed, great attention must be paid to the fire; for if it be not timely slackened when the liquid first boils, there is much risk of the still *running foul*, that is, boiling over through the neck of the still, which occurrence would of course spoil the operation; when, on the contrary, the improved stills, such as COFFEY'S and others, which have been already described, are used, no danger is to be apprehended from this evil. In rectifying faints, 80 under proof, the following method is used:—The spirit is mixed with the proper quantity of alkali, and the stills charged with this; the first portions that come over after the still is brought down, are collected separately, till the spirit runs at about proof, when it is turned off into another receiver; the result of this rectification—the common still being employed—will be about ten per cent. over proof. On rectifying a second time, the distillate at first marks forty-three per cent., and is collected till it indicates thirty; it is then conducted into another back until reduced to ten per cent. over proof, and the residual portion, after this strength, is received in the faints-back. A third rectification will afford a spirit of fifty-three per cent. over proof, or spirit of wine. In the second rectification, only one half the quantity of salts employed in the first operation is made use of; and in the third, it is customary to add about four pounds of animal charcoal, and ten pounds of coarse grained common salt, to every hundred gallons, to cleanse the still. At the distillery of Messrs. JAMES MULLENEUX and SONS, in Liverpool, where M. ST. MARC'S stills are erected, they can rectify twelve hundred gallons of proof ordinary wash spirit in ten hours, and obtain a product, if required, of sixty per cent. over proof, and stronger; but in that case a longer time is required to distil the whole contents, but the trouble of repeated distillations—as when the ordinary still is worked—is dispensed with, besides a considerable saving in labor and fuel is effected.

GENEVA.—This far-famed liquor has been long the subject of study among distillers. Many trials have been made to produce a spirit equal in quality to that imported, but with very indifferent success.

The subjoined particulars were communicated to the late Dr. THOMSON, by a gentleman who sojourned in Holland for several years, solely for the purpose of learning the process followed in the manufacture of the Dutch hollands or *geneva*. One hundred and twelve pounds of barley malt, and two hundred and twenty-eight pounds of ryemeal, are mashed with four hundred and sixty gallons of water, at 162° Fahr.; after infusion has taken place, cold water is added to bring the strength to forty-five pounds per barrel, or spec. grav. 1·047, at which strength, after it has cooled to 80° Fahr., it is run into the fermenting tun. To the contents of the fermenting back, which is about five hundred gallons, half a gallon of good yeast is added, fermentation speedily sets in, the temperature rises to about 90°, and the attenuation is complete in forty-eight hours. After attenuation of the wash, from twelve to fifteen pounds per barrel of saccharine matter remain undecomposed in the fermented liquor. The wash and grains are then introduced into the still, and the whole of the low-wines distilled over; these are subjected to a second distillation, and the distillate after rectification is the famous *geneva*. A few juniper-berries and sometimes hops are added in the rectification, to impart to the spirit a peculiar terebinthine flavor.

Some peculiarities are seen in this concise account of the process followed in Holland, namely, the imperfect attenuation of the wort, and the small amount of yeast employed in bringing it about. Double the quantity of spirits are obtained from the worts of the distillers in this kingdom, as is produced from those of Holland, according to the example just given. It is very probable that the large amount of yeast used by British and Irish distillers, and the last efforts tried to effect an attenuation as low as possible, are the very means which communicate a flavor to the spirit so different from the Dutch. The only liquor in this country which can bear any comparison with that of Holland, is perhaps the illicit product. A manufactory for the production of hollands was instituted some few years since at Maidstone, in Kent. It never became popular, and after languishing a few years, ended in bankruptcy. It has never since been revived. Indeed, according to the present state of the Excise regulations, it would be preposterous to attempt it, and this is only one of the numerous instances of the many obstacles in the way of private industry and enterprise, inflicted by the laws of this country.

British Gin is, for the most part, manufactured by the rectifiers of the low-wines of the Scotch and English spirit or whisky fabricators. The mode of procedure is to rectify the spirit from the faints by one or more distillations, and then to flavor it with berries and various other bodies. These processes are carried on generally in a most absurd and uncouth fashion, as appears by the following few receipts from the note-book of one of the most extensive and respectable distillery rectifiers in the kingdom.

The still is charged with three hundred gallons of liquor, and six hundred and fifty gallons of spirit from a previous rectification, to which are added—

95 lbs. German juniper berries,
95 lbs. coriander seeds,
47 lbs. crushed almond cake,
2 lbs. angelica root, and
6 lbs. liquorice powder.

The whole is well rummaged, distillation commenced, and after the worm is cleansed by the first portions drawn over into the faints-back, about one hundred and sixty gallons are run into forcing-back No. 4, then turned off into back No. 3, till it runs one-to-nine, or eleven per cent. over proof, when it is turned into faints-back No. 8.

About four hundred gallons are found in back No. 3. Liquor is run into back No. 4, to reduce it to fifty per cent. under proof; it is fined by throwing into it two pounds of alum dissolved in boiling water, and leaving it to rest for about eight hours, after which this *low gin* is pumped into back No. 3, containing the remainder of the charge to bring it to twenty-two per cent. under proof; then the whole is pumped into store casks for use; the result being one thousand one hundred gallons.

Another standard receipt for *Cordial Gin*: Take seven hundred gallons of the product of the second rectification—if the improved stills are used, the product of the first distillation answers—and mix with it the following ingredients:—

70 lbs. German juniper berries,
56 lbs. coriander seeds,
5 lbs. almond cake, crushed or broken,
1½ lb. orris root, broken,
2½ lbs. angelica root, cut,
½ lb. cardamom, or, instead of this,
6 lbs. liquorice powder are sometimes added.

Force the first running of the working, or about two hundred gallons, by reducing it to fifty under proof, adding three quarters of a pound of alum, boiled in two quarts of water. In adopting this receipt, make a double working of it, with twice the quantity of the ingredients. Work in the flavoring in the first charge of rectified spirits, having in the back two or three inches of the usual charge, to make up with liquor, and prevent the bottom of the still from injury by the charring of the large amount of ingredients depositing upon it. Turn the distillate into another back, and reduce to fifty per cent. *under proof;* force with a pound and a half of alum, and pump into fining cask; then charge with rectified spirits, and work into back containing goods from preceding charge. Run down gin from store cask, and make up to strength required—seventeen to twenty-two under proof.

Another receipt for the manufacture of Cordial Gin, the charge being nine hundred and fifty gallons, is the following:—

100 lbs. juniper berries,
70 lbs. coriander seeds,
2 lbs. orris root,
1 lb. angelica root,
2 lbs. calamus root,
½ lb. cardamom seeds.

The operations being the same as noted in the preceding.

For a *Fine Gin.*—the distillation of which is carried on, for the most part, in the same manner as the above, —take

960 gallons of spirit, hydrometer proof,
96 lbs. German juniper berries,
6 lbs. coriander seeds,
4 lbs. grains of paradise,
4 lbs. angelica root,
2 lbs. orris root,
2 lbs. calamus root,
2 lbs. orange peel,
80 or 90 lbs. of liquorice powder are occasionally added, to impart color and sweetness.

Plain or *London Gin* is made in the following proportions:—

700 gallons of the second rectification,
70 lbs. German juniper berries,
70 lbs. coriander seeds,
3½ lbs. almond cake,
1½ lb. angelica root,
6 lbs. liquorice powder.

For the manufacture of *West Country Gin*, the annexed is the process:—Introduce into the still seven hundred gallons of the second rectification, and flavor with

14 lbs. German berries,
1½ lb. calamus root, cut, and
8 lbs. sulphuric acid.

This gin is much used in Cornwall, and particularly in the Western counties of England; it is also used in making British hollands, and in that case is mixed with about five per cent of fine gin, reduced to twenty-two under proof with liquor.

For *Geneva.*—Charge of still being nine hundred and fifty gallons of second rectification, the proportions are:—

84 lbs. juniper berries,
112 lbs. coriander seeds,
6 lbs. cassia buds,
4 lbs. angelica root,
5 lbs. calamus root,
6 lbs. almond cake,
½ lb. cardamom.

Plain Geneva.—For nine hundred and fifty gallons of spirit of second rectification, take

84 lbs. juniper berries,
84 lbs. coriander seeds,
2 lbs. almond cake,
2 lbs. orris root,
2 lbs. calamus.

Another prescription for making Geneva—and one which is much esteemed—is the following:—Add to nine hundred and fifty gallons—

14 lbs. grey salts, and
4 lbs. white salts.

The rectification to be conducted with the usual care. At the second operation, add—

168 lbs. juniper berries,
74 lbs. coriander seeds,
12 lbs. almond cake,
8 lbs. grains of paradise,
8 lbs. angelica root,
1 lb. cardamom,
2 lbs. calamus.

It is of importance, and deserves attention, to consider, that in making gin with a high degree of flavor, the distillate, or flavored liquor drawn over, is very apt to turn blue on being diluted, to prevent which is very often a difficult task. In preparing such liquors, however, it would be the most advantageous and satisfactory way to have two stills, and to divide the charge between them. To one-half the amount, the whole of the spices and flavoring matters are added, and the liquid drawn off into two backs till it runs at eleven over proof. One of the backs is reduced as low as one in two, or fifty per cent. under proof, which ought always to be observed, as in making gin it should on no account exceed this strength, but may be two or three per cent. under, without being disadvantageous. About two to four pounds of alum are dissolved in hot water, and this solution is thrown into the back with the flavored spirit or goods, the whole briskly stirred, then pumped into a store vat, and left to fine over night; in the morning it will be clear, and is run into the back containing the second portion of the rectified spirit, without flavoring, and diluted to twenty-two or seventeen per cent. under proof.

In making gin of a less flavor, or where two stills cannot be employed, it is necessary to have a forcing-back to fine. To this forcing-back a small cask is attached, to enable the operator to pump off the low gin to the portion of strong in the back. The process followed in order to prevent the *bluing*, is to flavor and charge the still, and to run off into the forcing-back, till it is ascertained at the worm end that the spirit will not change color on being diluted with water, and when this happens, it is turned off into the working-back to the usual strength. The gin is then reduced in the forcing-back to fifty per cent. under proof, and the aluminous solution poured in, on the following day, when the liquor has clarified, it is pumped to the making vat to the remainder of the charge, and brought down to the strength required. If too weak, it may be raised by adding the best spirit of wine in the required quantity.

In France, an exceedingly fine gin is produced by fermenting a portion of juniper berries bruised with four parts of barley meal, or ground malt, proceeding throughout the succeeding part of the operation in the same way as when making grain spirit.

Another method practised is the following:—Boil during half an hour two gallons of bruised juniper berries in four gallons of water; put this into a barrel capable of containing six gallons; add to it at first four pounds of rye bread that has been dried and reduced to powder, then some aromatic, according to the fancy of the manufacturer, and two pounds of brown sugar. At the end of a month the liquor is converted into an agreeable wine, which, when distilled, affords a spirit much esteemed, and commanding a high price.

Having given the several incongruous mixtures used by the rectifiers in preparing their gins, the Editor now introduces a particular notice of each substance mentioned, with a description of the oil derived from it, and its properties, to enable the manufacturer to become better acquainted with the nature of the roots, seeds, and essences, that give to his liquors their peculiar fragrancy, astringency, *et cetera;* moreover, the information thus laid before him, may induce him to make use of those only that are serviceable in imparting the desired aroma. If spirits are at all wholesome (?), they must be more so in a pure than in a degraded state; consequently, it should be the aim of the fabricator to elevate rather than to deprave the taste of the consumer.

Cardamom.—The oil obtained from this seed is colorless, of an agreeable odor, and strong aromatic burning taste; the seeds are used in Abyssinia as a condiment, and in medicine; they are stimulant, tonic, stomachic, and carminative, and yield nearly five per cent. of essential oil, the composition of which is $C_{10}H_8$.

Grains of Paradise.—The volatile oil has a light yellow color, a camphoraceous smell, and a hot, penetrating taste; the seeds are esteemed in Africa as the most wholesome of spices, and are generally used by the natives to season their food; they are also used for medicinal and other purposes, as stomachic and cordial stimulants. Gins possessing a very peppery flavor, acquire it from grains of paradise, which yield half a per cent. of oil.

Almond Cake.—This is the residual cake of bitter almonds, after expressing the fixed oil. When distilled, it affords a volatile oil, which has a golden yellow color, an agreeable odor, and an acrid bitter taste. Substances or liquids flavored with bitter almonds may act injuriously, owing to the presence of hydrocyanic acid.

Angelica Root.—This root grows most abundantly in Northern Europe; its taste is at first sweet, then hot, aromatic, and bitter.

Calamus Root.—The taste of this root is due to the oil, which is sharp and sweetish; the yield of oil is about one-hundredth per cent. It is obtained by distilling with water, and is used for flavoring aromatic vinegar.

Orange Peel.—The peel of the orange yields the oil proper, which has the strong odor of the rind.

Lemon Peel.—The oil is obtained both by expression and by distillation. It is chiefly imported from Portugal, Italy, and the South of France. Pure lemon oil is very fluid, of an agreeable odor, and colorless. Its taste is pleasant but pungent, and it is, therefore, often used in culinary purposes as a substitute for the peel; the flavor, however, which it imparts, frequently savors of turpentine, and is never so agreeable as that communicated by the fresh rind of the fruit. Oil of lemon and oil of turpentine are isomeric.

Juniper Berries.—What the distiller prizes in this berry is its volatile essence, which is an oily liquid, isomeric with the preceding, and with oil of turpentine; their smell is also very similar, hence the origin of the supposition that London gin is sometimes mixed with the latter. Oil of juniper is the most powerful of all diuretics, and gives to the urine the smell of violets. It promotes perspiration and relieves flatulency; consequently, gin is recommended in many diseases of the urinary organs.

Coriander.—The seeds have a strong smell, and medicinally are considered as stomachic and carminative; they are used in sweetmeats, in certain stomachic liqueurs, and, in some countries, in cooking. They contain about half a per cent. of volatile oil, to which they owe their fragrancy, and on this account the seeds are used in rectifying operations.

Orris Root is the root of *Iris Florentina*, a white flowering species of iris found in the South of Europe. It has an agreeable odor resembling violets, and is sometimes used in perfumed powders. In its dried state it is employed as a pectoral and expectorant, and is sometimes made into little balls for issues, called orris peas.

Liquorice.—A plant of the genus Glycyrrhiza. The root abounds with a sweet juice, much used in demulcent compositions.

Cassia.—This plant furnishes buds which consist of the calyx surrounding and nearly encircling the young ovary. They bear some resemblance to a clove, but are smaller, and when fresh have a rich cinnamon flavor. They are used for the same purposes as cinnamon and cloves. The bark and oil are powerful stimulants. Oils of cassia and cinnamon, when quite fresh, have the formula $C_{20} H_{11} O_2$. On exposure to the air they rapidly absorb oxygen, yielding a considerable quantity of cinnamic acid.

It occurs to the Editor that most of the roots or seeds have, so far as their oils or essences are concerned, very analogous properties; and since their virtue in distillation with the spirit is to communicate their oily or fragrant principle, why not add a few drops of each of the oils at once to the pure spirit, to procure the desired liquor, and by this means obviate the necessity of distilling, and the risk of injury to the stills by the mixtures mentioned, which appear to have no atomic rule for their basis?

BRANDY.—This alcoholic liquor forms an extensive trade in the South of Europe, and it is generally obtained from the high-colored, white, or pale-red wines of those countries, but is often manufactured from inferior articles, such as the refuse wine and the marcs of the wine press.

Distillation of the wines is the only thing necessary to procure this spirit; hence, the richer the wine in alcohol, the greater will be the yield of brandy. A simple test with an alcoholometer will determine for the distiller the value of the wine as to the yield of brandy; but many other circumstances, independent of the manufacture, enhance the quality of the product.

Thus, the white wines do not always afford more alcohol than the red, but the spirit is of a much finer quality from the former. The reason of this is, that they contain more of the essential oil of the grapes. It is also a singular fact, that those wines which carry with them a certain taste of the soil, communicate it to the brandy derived from them by distillation; thus, the wines of Selluel, in Dauphiné, give a certain brandy which has the flavor and the taste of Florentine iris; those of St. Pierre, in Vivarais, give a spirit which smells of the violet, and so of many other varieties.

Wines of the countries nearest the Mediterranean furnish the largest proportion of brandy, which diminishes as the grapes grow in more Northern countries. The wines of the South of France yield one-fourth of brandy, some even one-third, while in the North of France, only about one-eighth, or even one-tenth of brandy is afforded.

The fabricator of the better qualities of brandy invariably distils the white wines; first, as was before stated, because often a greater yield of brandy is obtained, and this of a better quality than from the red wines; and, secondly, because those wines fine sooner, so that they may be distilled into brandy before the red wines are ready for this operation.

The stills employed on the Continent are those of DEROSNE and LAUGIER, in France; of PISTORIUS, in Germany; ST. MARC's is also used in the distillation of wine. With these stills, the spirit comes over of any requisite strength, up to the strongest spirit of wine; but when the ordinary still is employed, the receiver is changed when the vapor arising from the boiler only feebly ignites, and the *eau-de-vie-seconde*, or *repasse*, is collected by itself, till the whole of the alcohol in the wine has been exhausted. The liquid remaining in the still is called *vinasse.*

The *campaign*, or distilling season, in France, is from the beginning of October to the end of May.

The following is an average of the yield of brandy which some of the wines afford by distillation:—

1000 Litres of wine of St. Gilles, in the environs of Montpellier, afford of 3/6 brandy,.....	150	litres.
" " of good wine of calcareous soils, ...	140	"
" " of wines of fertile soils near Montpellier,	100	"
" " of wines of soils producing much grapes,	100	"

The brandy, as sold in France, is generally of two degrees of gravity; these strengths are thus designated —*à preuve de Holland*, and *à preuve d'huile;* the former varies from 18° to 20° of Beaumé. The stronger liquids are valued according to the quantity of *eau de vie*, or brandy *à preuve de Holland*, that a given quantity will furnish on the addition of the proper proportion of water. These strengths are usually twelve, namely, *five-six*, *four-five*, *three-four*, *two-three*, *three-five*, *four-seven*, *five-nine*, *six-eleven*, *three-six*, *three-seven*, *three-eight*, and *three-nine*, but the last is rarely made. The meaning of these strengths is understood in the following sense:—if a spirit be five-six, five parts of the spirit will give a liquor *à preuve de Holland*, when added to six measures of water; if three-six, three measures when added to six of water will yield a spirit of the same standard, and so of the remainder.

The spirit five-six strength is of a specific gravity 0·9237, or 22° Beaumé; but all the other strengths are subject to variation on account of the uncertainty of the strength *à preuve de Holland*, as before shown. Wines, when distilled carefully from a clean apparatus, yield a distillate which is colorless or nearly so, and when it is wished to retain it in this state, vessels of glass or stoneware are employed. After being put in casks and left in them, the clear liquor acquires a little color by extracting the soluble matters of the wood; the flavor, however, is not materially affected if the casks be not newly made; when new casks are used, the tannic acid of the wood, which is generally oak, communicates a deep color and astringency of taste which is quite foreign to the brandy.

The brandy from different localities, and even from a different variety of grape grown on the same place, possesses, as already remarked, an aroma characteristic of the wine whence it is obtained, and which is readily perceptible to those well versed in the trade. An experienced taster will readily distinguish the brandies of Languedoc, Bordeaux, Armagnac, Cognac, Aunis, Rochelle, Orleans, Barcelona, Naples, *et cetera;* further, he can say from what species of fruit it is derived; and he will also discern minute shades of difference in the qualities of various brandies from the same source. Real cognac is obtained from the distillation of the choicest wines, every regard being paid to the proper degree of cleanliness which should be observed in the various utensils through which it has to pass. In the improved forms of still a very superior article is obtained from inferior wines, but the proportion of essential oils in such wines divests the brandy of that aromatic flavor which is an inherent property in the better sort of wine, and which is observable in a very distinct degree in the brandies procured from them.

An inferior variety of brandy, or *eau de vie de Marcs*, is obtained by distilling the dark-red wines of Portugal, Spain, and other wine-growing countries, the lies deposited by wines on keeping, the marcs or refuse of the grapes from the vine-press, the scrapings of wine casks, *et cetera.*

Distillation is carried on in the ordinary way, but as the flavor is not so much regarded, the spirit is drawn off rapidly, and at a high temperature. The marcs from the vine-press are prepared for the purpose of distillation by breaking the cakes up into pieces, and throwing them into water. A temperature of 70° to 80° Fahr. is kept up, and in the course of a short time fermentation sets in; when this has ceased, the solution is racked off and distilled. The first distillate has a whitish color, and is called *blanquette*, but this on redistillation yields a spirit of 22° or 24° Beaumé. One pound of brandy is produced from eighty-five to ninety pounds of cake.

The fermentation of the cakes is sometimes effected in large pits, where they are covered with earth. The progress of fermentation is known by thrusting the hand into the heap. When the temperature decreases, the fermentation is said to be finished; the contents are then taken out, water in proper quantity added, and distilled. By this process a hundred pounds of marcs yield one pound of brandy. When such liquors are distilled, the sedimentary matter subsides, and is apt to carbonize on the bottom of the copper still, and thus communicates a smoky flavor to the distilled liquor, in addition to a hot fiery taste proceeding from the essential oil—fusel oil or amylic alcohol—of the skin of the fruit. AUBERGIER has proved that a few drops of this energetic compound are sufficient to taint a pipe of one hundred and thirty-three gallons of pure spirit. In some distilleries the apparatus is furnished with agitators to keep the contents in motion. Other manufacturers insert into the body of the still a basket to retain the sediment accompanying the fermented liquor, and thus contact with the lower part of the still is prevented. M. REBOUL'S process is to inject steam from a boiler into the still by means of a coil of piping. The stills in this case are large wooden boxes, to which worms are adapted in the usual way, and the whole of the alcohol is driven over by steam heat. M. CURANDAU'S apparatus consists of a still, the neck of which is as wide as the body, and three feet in height; brackets are placed at the distance of nine inches in the neck of the still, which support several partitions; these are provided with short pipes, pierced with holes, to allow the vapors to circulate freely from the body of the still. The neck being affixed, and the first partition introduced, wine lies are poured in, which are filtered by the perforated partition; then the second, and a further quantity of lies, and so on till all the partitions are inserted and the lies are about six inches thick on each.

If the liquid drained from the marcs or lies be not sufficient to fill the still, water is added to make up the proper quantity. Heat is then applied, and the steam, as it passes off, expels the last portions of spirit from the solid particles retained by the partitions in the neck of the still. Most of the inferior kinds of brandy contain an acid which partly unites with the oil from the grapes, rendering the taste of the spirit unpleasant; agitation with a little quicklime has been recommended, which not only removes the acid, but also the oil in a great degree. The matter left in the still when dried and burned, yields an alkaline carbonate, which is often preferred to potassa, or the commercial article, in dyeing operations.

Spirits of this class are used by the lower order of people in France, but on account of their hot fiery taste, they are often preferred in England and other Northern countries to a more genial produce. Cognac and Armagnac brandies contain about half their weight of water, and owe their fragrancy to the smaller amount and less disagreeable nature of their fusel oil, so that the aroma, indigenous to the wine, is readily perceptible in their odor and taste.

Enanthic ether is another constituent which imparts a nice aroma to wines, and passes into the brandy. Pelouze first proved this odorous principle of wine to be a compound ether. Mulder detected the same in the oil of grain-spirit, and in other fermented liquors, and it is from this that quinces derive their distinctive perfume. The specific gravity of this ether is 0·86217, and its composition the following:—

	Atomic weight.		Centesimally represented. Theory.		Pelouze.		Muspratt.
18 Eqs. Carbon,.....	108	..	72	..	72·020	..	72·006
18 Eqs. Hydrogen,..	18	..	12	..	12·050	...	12·103
3 Eqs. Oxygen,....	24	..	16	..	15·930	..	15·891
1 Eq. Enanthic ether,	150	..	100	..	100·000	..	100·000

Or—

	Atomic weight.		Per cent.
1 Eq. Ether,..................	37	....	24·66
1 Eq. Acid,....................	113	....	75·34
	150		100·00

In cognac, *et cctera*, it is probable that the aromatic portion condenses sooner than a strong spiritous fluid, for the first sorts are only distilled to the spec. grav. 0·922; and by redistilling to obtain a stronger alcoholic liquid, much of the aroma remains in the residuary matter of the alembic.

The effect of heat on several of the substances contained in wines, merits the attention of the distiller. A little too high a temperature might destroy a whole distillate, as empyreumatic and other products would be generated. When, to save expense in carriage, the spirit is rectified to a much higher degree than the above, the dealer, on receiving it at Paris, reduces it to the market proof strength by the addition of water or of a little fragrant weak brandy; but in this manner the brandy produced is not equal to that derived from the distillation of Cognac wine, at an incipient heat. This may be readily proved by submitting to distillation, with every precaution, brandy of a superior quality; if the resulting spirit be then brought down to the ordinary strength with water, it will be plainly perceived that the liquid has been considerably deteriorated by the operation. Genuine French brandy evinces a red reaction with litmus paper, owing to a minute portion of acid; it also contains an ether, and, when kept for a considerable period in casks, it acquires an astringency which impairs its quality.

The brandy sold in England is, for the most part, artificial—the fabrication of the rectifying distiller. The following receipt is given by Dr. Ure:—Dilute the pure alcohol to the proof pitch, and add to every hundred pounds weight of it from half a pound to a pound of argol—crude winestone—dissolved in water, some bruised French plums, and a quart of good cognac. Distil this mixture over a gentle fire, in an alembic provided with an agitator. The addition of brandy and argol introduces enanthic ether, and if a little acetic ether be added to the distillate, the whole imparts the peculiar taste of genuine cognac brandy; color with burned sugar, if necessary, and add a little tannic acid to impart astringency.

An example is here given, on the small scale, for the artificial formation of this beverage; but the course followed by the rectifier is somewhat different, as will be seen from the subsequent few examples, which are transcribed from the private work-book of a very extensive rectifying distiller. The source is generally the common low wines of the grain distillers, which are rectified in the usual way, by distillation with caustic salts, as has been already described.

To every five hundred gallons of this spirit, about twenty-five gallons of the best French wine-vinegar are added, and the whole well rummaged in the mixing-back; the mixture is then pumped into the still, and a further quantity of a weaker spirit run into the back, in order to clear it of the last traces of vinegar—this liquor is also pumped into the still to make up. From fifty-six to sixty pounds of coarse-grained common salt are now mixed with the liquid in the still, together with from eight to ten pounds of concentrated sulphuric acid, keeping the whole in brisk motion during the addition of the latter, to protect the still from the action of the acid. The fire is then lighted, and the still brought down and worked till the spirit shows a strength of fourteen over proof, or one-to-seven. It is customary to turn off into the faints-back at a lower degree of strength, and collect the remaining quantity of faints; in such a case, however, the quality of the spirit is not so good. From every five hundred gallons of the charging, five hundred to five hundred and ten gallons of spirit, marking forty-two per cent. over proof, are obtained. This is mixed with from four hundred to four hundred and fifty gallons of liquor, and pumped into the British brandy store-vat. Twenty to twenty-five gallons of *fruit tincture*, fifteen gallons of brandy flavor, and eight to ten gallons of good coloring, are then introduced into the piece, the whole well rummaged, and left to fine. It is considered an improvement to fine with skimmed milk. Some distillers prefer to introduce distilled vinegar in the proportion of fifteen to twenty gallons to a thousand gallons of the compounded liquor in the store cask, instead of adding it previous to distillation, as before mentioned.

Another receipt, which is followed for the most part in the distillery from which these details were obtained, using a multiple of the numbers, is next given.

Three hundred gallons of proof spirit are distilled with the proper addition of caustic salts, taking all the precautions mentioned in the preceding, under Rectification of Spirits, and the distillate is received into the spirit-back till it runs at ten over proof. The remaining spirit is turned into the faints-back, and is then made up with four hundred and fifty gallons of spirit, twenty-two under proof, twenty gallons of *prune tincture*, twenty gallons of distilled vinegar, and eight gallons of good coloring matter.

When flavored faints are cleansed, charcoal is employed in the rectification with sulphuric acid.

Raspberry Brandy.—In manufacturing raspberry brandy, the subjoined is the process:—For one thousand gallons of the brandy, take

460 gallons of raspberry tincture,
115 gallons of cherry tincture,
240 gallons of sweets,
96 gallons of British brandy, 22 U.P.
89 gallons of liquor;

rummage the whole well, and force or fine with isinglass.

Cherry Brandy.—For the fabrication of one thousand gallons, take

575 gallons of cherry tincture,
253 gallons of sweets,
92 gallons of British brandy 22 U.P., and
80 gallons of liquor,

the whole to be well agitated in brandy-piece, and forced with isinglass.

Raspberry tincture is made as follows:—Take a brandy-piece with head out, and screen over the cock; put in fifty gallons of clean rectified spirit of twenty-two under proof, then fill the cask with raspberries. In three weeks or a month, draw off the whole of the tincture into a clean cask, and add to the fruit, a second time, twenty-five gallons of spirit of twenty-two under proof; let this remain upon the raspberries a month longer, and then draw this off, and add it to the first tincture; after which the whole of the tincture remaining in the fruit is to be pressed out and added to that already obtained. The cake is then broken up and steeped in a rum puncheon with the head out, forty gallons of spirits are added, the whole contents briskly agitated from time to time for three or four days, and pressed well after drawing off the solution. This liquor is employed in making up the raspberry brandy instead of water.

Cherry tincture is made in the same manner as the raspberry, by substituting the one fruit for the other.

For prune tincture cover fifty-six pounds of prunes, thoroughly broken up, with twenty gallons of clean spirit of wine, and after being allowed to stand for eight or ten days, rack off; the refuse fruit is washed twice with liquor, and the residue is then thrown away.

Many rectifiers prepare a brandy flavor as follows:—To one hundred gallons spirit—clean faints, fifty-four over proof—add

100 gallons of good strong vinegar,
4 gallons of spirit of nitre,

in a back, and mix the whole thoroughly; cover closely, and the next day run it into the still with

8 lbs. of nitric acid,
10 lbs. of almond cake,
5 lbs. of orris root, and
2 lbs. of lemon peel;

work the still slowly, and turn off at proof strength.

In making up brandy, ten per cent. of the above flavoring is employed, but more or less may be used to suit the taste of the consumer.

Brandy is distilled in Switzerland from the refuse of the grapes after the juice is pressed out, as follows:—Large casks are filled with the skins, which are squeezed as compactly as possible, and are covered closely to prevent the access of air; fermentation usually commences in about three days, and when it has finished, which requires a considerable time, it is deemed ready for the still. When the distillation is to take place, the fermented mass is mixed with a due proportion of water, to reduce it to a proper consistence for the action of the fire, which is moderately applied to prevent empyreuma. It is said that a vessel containing thirty-two cubic feet of this material will yield ten gallons of pure brandy.

RUM.—Molasses is the name given to the sirup which remains after the crystallization of sugar; it is, in fact, the mother liquor of sugar. This sirup, diluted with a sufficient quantity of water, undergoes the vinous fermentation, and by distillation yields a spirit, called in the colonies *rum*, or *taffia;* the name given to it, in the Isle of France and Madagascar, is *guildive.* This spirit is of excellent quality, very *recherché* when prepared with proper precaution, and particularly relished when it is very old. The best rum is that which is made solely from molasses; but that, in the fermentation of which is left the debris of the sugar-cane, froth, *et cetera,* always retains a sharp disagreeable acid, and frequently acquires an empyreuma, on which account it is given to the negroes who work in the sugar-houses, and is consequently called *negro rum.* In the fermented liquor from which the rum is distilled, acetic acid sometimes exists in large quantities, accompanying the ardent spirit, without forming ether; but it is the nature of this acid to produce, in the heat and vapor of distillation, a certain portion of strong spirit containing acetic ether, which, from its extreme volatility, rises in the first process of distillation, giving to the vapor a most disagreeable taste and smell; hence the colonial saying, that the rum becomes *too hot* if rectified like the European spirits. The cause of this is easily explained: the rectified spirit only forms a part of the charge of the still, and contains, nevertheless, *all* the acetic ether. The skilful fabricators, who pride themselves on making these strong spirits most agreeable to the taste, take great care in cleaning the keeves from all kinds of vegetal matter or refuse incapable of producing vinous fermentation, or such substances as have a tendency to putrefy, because the putrescent matter retards the action, and gives a savor which is communicated to the distilled spirit. The Chinese, who prepare the famous arrack of Batavia, which, without contradiction, is the best of all rums, take much care in rectifying it, mixing with it during distillation a composition called *ragie,* in which is cinnamon and anise-seed, in such proportion as not to be perceived either by smell or taste, being only sufficient to do away with the otherwise nauseous odor of the liquor. The Madagascars throw in leaves of trefoil. The Asiatics mix with it the bark of a kind of thorny acacia, called *pattay.* Some persons put into the still, with the grape, the leaves of a tree named *attier* in the East Indies, and *pommier cannelle* at St. Domingo—*œnona squammosa*—which have a light agreeable odor. Others have tried, with success, the mixture of peach leaves. All these substances impart to strong liquors a pleasant bouquet and taste, which prove that they are used to disguise the smell of the spirit, and to give it unctuousness.

The chief seats of the distillation of this spirit are the East and West Indies, America, and France. It is strange that the Chinese, who produce so much sugar annually, and who, consequently, might manufacture large quantities of rum from molasses, have not hitherto attempted to distil this article.

The Editor transcribes the following account of the fabrication of this spirit in the West Indies, from MOREWOOD:—

From the liquor of the cane, which runs warm from the coppers through a trough to a receiver prepared for that purpose, the skimmings are taken, and, with some of the liquor itself, are pumped from a cistern containing from three hundred to eight hundred gallons, when the fluid is mixed with water and molasses in the proportion of twenty-five gallons to one hundred. If this mixture be sufficiently blended together in the vats, which in some plantations amount to thirty, it is covered over with boards or mats of plantain leaves, and allowed to ferment for three or four days, or longer, should there be a want of yeast or other ferment to make it work, which often occurs at the commencement of the season. When reduced to a due degree of acidity, which is ascertained by the subsidence of the fermentation, it is run into a still proportioned to the vat, and wrought off as low-wines, in which state it is put into the still again. The first run, or discharge, after it is thus returned to the still, is taken off for *high*-wines, as they are termed, or strong rum, in the proportion of 25 to 300 gallons, the strength of which, when tried by a glass-bead instrument, is from 18° to 22°. The second run of the still, which is drawn off in cans, and carried by negroes to another vessel, is of a strength from 23° to 26°. From these two runnings of the still, the rum exported from the colony of Demerara is made up. Any deficiency in the strength of the second distillation is compensated by an addition from the first, which is always stronger than that exported, and of too ardent a nature to be used by itself, 25° being colony proof.

In the Windward Islands, one-third of the skimmings is mixed with one-third of the lies, and one-third of water. When these begin to ferment, which they usually do in twenty-four hours, the first mixture of molasses takes place in the proportion of six gallons for every hundred gallons of the fermenting liquor, and a day or two afterwards an additional quantity of molasses is added. The fermentation is tempered by the addition of cold or warm water. *Dunder*, a term unfamiliar to the ear of a European distiller, is the lies or feculencies of former distillations, serving all the purposes of yeast in the fermentation. It is derived from a Spanish word, *redunder*, the same as *redundans* in Latin, and is well known among the planters in the West Indies. The attenuating properties of this ferment are such, that the materials with which it is mixed are said to yield a much greater proportion of spirit than could be obtained if they were fermented without it: it serves the same purpose as jalap mixed with molasses, which has been sometimes employed in Great Britain for cutting down the frothy head at the close of fermentation; and it is usually preserved from one year to another for this purpose, in such large quantities as to fill most of the backs or fermenting tuns. Dunder soon becomes covered with so thick a film as to exclude the air, and the sediment leaves the intermediate fluid pure, of a bright amber color, which, when carefully drawn off, is employed as already described, in proportions suited to the nature of the fermentation; to this dunder may be attributed the best flavor of the rum. Besides this very essential ingredient, various mixtures are used in the fermenting process, such as tartar, nitre, sea-water, or common salt.

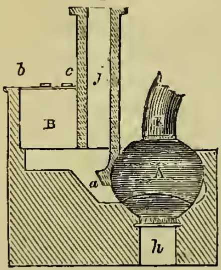
In well-conducted distilleries, much attention is paid to the management of the proper quantity of water employed in the preparation of the liquor. Before commencing, the various boilers and keeves are thoroughly washed and freed from saline matter, by hot or cold water.

In the beginning of the distilling season, more sugar is employed than is afterwards found requisite; the reason of this is, that the distiller has no good lies, and very little molasses to add to the mass; besides, the scum or froth from the sugar is not so rich from the first boiling of the season as in the months of March, April, and May, which is the most favorable time. The following proportions succeed well at starting:—For every one hundred and thirty-six gallons content of the vat, pour in sixty-one gallons of scum, seven of molasses, and sixty-eight of water. When the lies or dunder are good, equal quantities of skimmings, lies, and water are employed, and for every hundred gallons of this mixture, ten of molasses are added. Should the pressing-mill be not in operation, and skimmings cannot be obtained, it is found advantageous to employ equal parts of lies and water, and with every one hundred and thirty-six gallons of the compound, twenty-seven of molasses are mixed. With mixtures such as these, the distiller can obtain from ten to fifteen per cent. of rum, and other products; but this quantity depends very much upon the quality of the ingredients operated upon, as also upon the state of the weather and time of distillation; hence, an intelligent distiller varies the proportion of the bodies submitted to fermentation.

Rum differs from what is termed sugar spirit, for it contains more of the natural aroma, or essential oil of the sugar-cane. When the West India distillers have enough of matter, they mix the water with it, and allow it to ferment in the ordinary way; the fermentation proceeds slowly at first, on account of the scarcity of the yeast, but as soon as sufficient ferment has been produced, it operates quickly on the whole mass till the attenuation is finished. This liquid is then distilled, and produces a spirit of great strength, nearly equal to alcohol, which they name *double-distilled rum*, or *double rum*. The spirit is more easily concentrated if much liquid be submitted to distillation, but in the course of this operation it yields such a large amount of oily matter, that it cannot be used for a considerable time. For preserving the rum, either for exportation or other purposes, it is found useful to make the double rum so as to form alcohol, or ardent spirit. In this state it occupies only half the volume of the ordinary liquid, and can be diluted with water to suit the taste of the consumer, or to the common strength.

The still for the most part used in those islands, and by which a great saving of fuel is effected, is represented in the annexed engraving—Fig. 74. It consists of two distinct parts: A is the boiler, and B the vessel which contains the fermented wash, to be heated previous to its introduction into the still. The boiler and preparer are placed in such relative positions, that the heat of the fire, after doing the required service to A, passes under the vessel, B, and thus communicates heat to the liquid. The plan of the construction is seen in Fig. 75, where the arrows show the course of the flue under both these vessels. The waste heat enters the chimney by a damper-opening at the back. *a* is the passage from the fire under the preparer; *b*, a lid screwed firmly on the vessel, B, which resists the pressure of any vapor generated in this vessel; *c*, a safety valve; *j*, the chimney; *h*, the fire-door; K, the tube which carries off the vapors to the condenser attached to the alembic, which communicates by a pipe not shown, with the preparer, B.

Fig. 74.



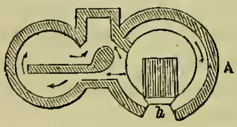
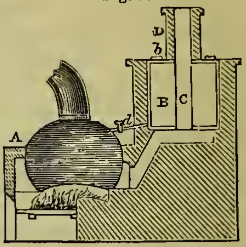


Fig. 75.

When operations commence, the preparer is filled with the fermented liquor, and likewise the still, to a proper height; the fire is then lighted, and the liquid in the alembic very soon boils, and that contained in the preparer at the same time acquires a temperature approaching ebullition, by the waste heat communicated from the flue beneath this vessel. As soon as the matter in the boiler becomes exhausted of its alcohol, the fire is slackened, the residuary liquid drawn off by the discharge-cock, and the boiler replenished by opening the stopcock of the pipe which connects the alembic and preparer. The fire is again urged, the vessel, B, refilled with fresh liquor, and the distillation proceeded with, as in the previous instance.

Another form of apparatus used by the West Indians is seen in the engravings, Figs. 76 and 77. This still, and preparer, differ only slightly from the preceding. A is the boiler, B the preparer; and the mode of communicating heat to the latter is seen in the plan—Fig. 77—where the course of the heat from the fire is indicated by the arrows, till it enters the circular space of brickwork called the *bonnet;* from this it traverses the perpendicular pipe, C, passing through the middle of the preparer, and thence into the chimney, D. *b* is the lid of the preparer, and *d* a pipe that connects this vessel with the boiler. This arrangement has an advantage over the common furnace, by the larger proportion of heat it communicates to the boiler on account of the winding course of the flue, and any extra caloric is made useful in heating the liquor in the vessel, B.

Fig. 76.



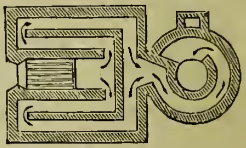
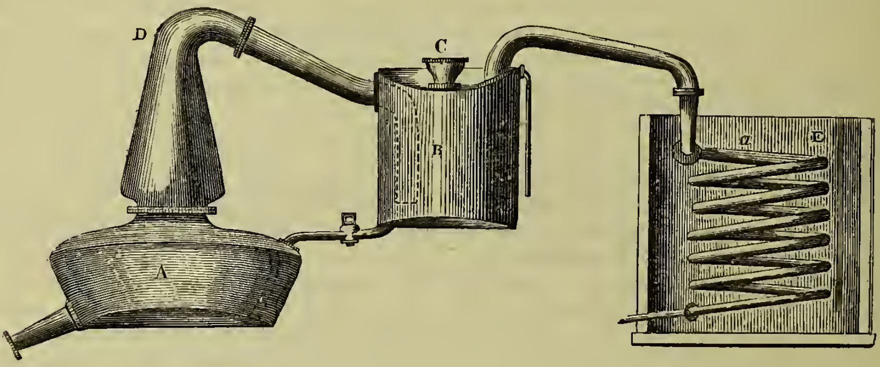


Fig. 77.

The annexed form of still—Fig. 78—is frequently exported to the West Indies. It consists of the boiler, A, with an elongated conical head, D; the preparer, B, into which the wash is introduced by the funnel-basin, C; and the condenser, E, where the spiritous vapor is liquefied in passing through the numerous convolutions of the worm, *a*. The peculiarity of this form of still consists in the communication of the pipe, D, with the preparer, B, by which means the vapor from A is partially condensed in the preparer. The vapor is carried to within a few inches of the bottom of the vessel, B, as shown in the figure by the dotted continuation of D; the liquor in B is heated by the aqueous vapor condensed in it, as well as by the spiritous vapor which passes through it uncondensed to the worm, *a*. By this arrangement fuel is economized, and a stronger spirit is procured at one distillation.

Fig. 78.



In some of the islands, a still makes about two hundred and twenty gallons of rum daily; these are produced from about five hundred and thirty gallons of low wines, or a hundred and thirteen of rum may be procured from twelve hundred gallons of wash. This liquor is so strong that olive oil will sink in it, and by one rectification it is made to approach the strength of alcohol. The process of distillation is in general slow, and much caution is observed in the condensation of the spirit. To provide against a scarcity of water, which often occurs in the islands, they preserve in large tanks a sufficiency of rain-water to enable them to mix the molasses, *et cetera*, and to cool the worm of the still. As the water becomes heated in the worm-tub, it is carried to coolers or cisterns, and when cold it serves again for refrigeration. In most of the islands, the curing-houses for sugar, and the distilleries for rum, are constructed on the sides of canals, and the canes carried to them from the plantation, either in boats or by negroes Five or six immense copper boilers are kept in each of these houses, and the greatest cleanliness is observed in the distillery; a precaution of immense importance, which must contribute largely to the strength and purity of the rum. In Jamaica, the operations go on without intermission; the negroes being formed into divisions or relays, who relieve each other at regular intervals. The richness of flavor peculiar to this spirit, and which has rendered it famous in all parts of the world, is undoubtedly derived from the raw juice and the fragments of the sugar-cane, which are mashed and fermented with the other materials in the tun. The essential oil of the cane is thus imparted to the wash, and carried over in the distillation; for sugar, when fermented and distilled by itself, yields a spirit possessing no peculiar flavor different from other ordinary alcoholic liquors. Time adds much to the mildness and value of rum; but the planters, by the addition of pine-apple juice, impart to it the virtue which is conferred by age.

A superior quality of rum is manufactured in the colony of Demerara, where, according to the account of Bolingbroke, distillation has been carried to a high state of perfection by the perseverance and skill of several scientific men, who have caused the rum of this district, and that of Essequibo, to be as much prized in the American market as Jamaica rum is relished in England. In Brazil, large quantities of rum are manufactured, which are exported to America and to most European nations. The process followed is rude and simple. The wash is generally fermented in large earthen jars, but no fixed rules, to regulate the quantity of molasses which should be operated upon, are observed. A strong lie is said to be poured on the sirup, in order to thicken and purify it. The lie is obtained by burning a plant of the *polygonum* species, called by the Indians *cataya*, and infusing the ashes in water. This plant has a bitter pungent taste, and is considered of use in making rum. The stills are mere earthen jars, with a long narrow neck, on the top of which is placed a head or cap, having at one side a pipe of about six inches long; to this adapter a copper tube, four feet in length, is connected, which passes through an earthen vessel sufficiently large to hold a quantity of water for the condensation of the spirit, and this contrivance is made to answer the purpose of both worm and worm-tub.

Until lately, it was a custom with the planters to dispose of their molasses to small distillers, who, possessing one or two of these stills, procured a living by making rum; but the introduction of copper stills from Europe has produced such a reformation in distillation, that at present the whole quantity of molasses resulting from the sugar-houses of the plantations is manufactured into rum by the proprietor.

To calculate the cost of rum to the sugar planter is difficult: in general, it is estimated that one-fourth of the entire produce of a plantation may, in point of value, consist of rum, and, accordingly, one-fourth of the expenditure may be taken as the first cost of the rum, and the remaining three-fourths as that of the sugar. Some say that the charge of making rum bears a similar proportion to that of home-made spirits, but this is an erroneous assumption. Rum is made from the molasses, or that part of the cane-juice which will not crystallize into sugar, as also from the scum which is taken off during the saccharific process, and which in sweetness is equal to one-fifth of molasses. Take, as a standard, a distillery on a plantation producing 250 hogsheads of sugar, yielding 15,000 gallons of molasses, and scum equal to 5,000 gallons, netting in all 20,000 gallons of molasses. These would produce about 15,000 gallons of proof rum, which, when brought to the British market, would be reduced by the voyage to about 13,500 gallons, the average loss being ten per cent. These would cost the manufacturer throughout the islands from 1s. 1d. to 1s. 4d. per gallon, independent of all charges for puncheons, freight, commission, and other unavoidable expenses.

From this statement, it must appear that the distiller of rum has little or no profit, but being the grower of the material, and having his capital embarked in the trade, he is compelled to manufacture it from necessity, and the sooner he can turn the article to account the better he is enabled to bear loss and meet his engagements.

In France, a large quantity of spirit is annually manufactured from the molasses of the beet-root sugar factories, of which a great many exist in that country. The better sort of molasses remaining after the refining of the sugar of the colonies, is too valuable to be converted into rum, but sometimes the inferior article is disposed of in this way. On the arrival of the molasses at the distillery, they are emptied into large cisterns perfectly free from any dampness which would cause them to ferment, and here they remain till required for use. The fermentation of molasses presents some difficulties; they must be properly mixed with water, in such proportion that the resulting liquid will not exceed 8° of Beaumé's areometer, at a temperature of 20° C. = 68° Fahr., which should always be the heat of the mixture. When too little water is used, the fermentation sets in too rapidly, the temperature becomes higher, and the acetous fermentation speedily ensues; on the contrary, when too much water is employed, the fermentation is inactive; in consequence of the low temperature a longer time is required, and generally bad results follow. These inconveniences can be overcome by attention to the directions about to be given.

It sometimes happens that the fermentation of the saccharine solution suddenly ceases, and cannot be revived by an increase of temperature, or addition of a stronger solution of molasses. This phenomenon is owing to the presence of lime and potassa, which are contained in almost all the molasses of beet-root sugar, and, in consequence of the alkaline reaction imparted by these substances to the liquid, the conversion of the sugar into alcohol is interrupted. This antifermenting property of alkaline bodies is very easily removed; it suffices to add a certain quantity of sulphuric acid to neutralize them and form sulphates, in which state they are inert. A slight excess of acid might be employed, without prejudice to the proper degree of attenuation, or to the taste of the product; for the molasses always contain salts of organic acids, with potassa, *et cetera*, which are decomposed by the sulphuric acid, and the organic acids are liberated. The sulphuric acid is to be added when the water is mixed with the molasses, and may vary in amount from half a per cent. of the weight of the latter, as a minimum, to one and a half per cent. as the maximum quantity. The molasses being comminuted with the water and acid, so that the solution stands at 8° of the areometer, about two per cent. of their weight of fresh barm, pressed and previously diluted with water, is added; the liquid is then strongly agitated, and left to ferment. The fermentation is made in a number of tuns whose size corresponds with that of the distilling apparatus, and by this arrangement the distiller is enabled, when the fermentation in one tun is finished, to distil the contents directly.

The fermented wash should never remain longer than twenty-four hours until it is distilled. From this it is manifest, that the distiller should be furnished with as many fermenting vessels as will permit him to have the contents of one tun daily ready for distillation, and one ready for charging each day; the intermediate tuns being in a higher state of fermentation, as their turn brings them nearer the proper time of their being distilled. All the tuns should be well covered, to prevent the contact of the atmosphere, and the acid fermentation taking place.

If molasses be fermented and distilled merely for the alcohol which they yield, the preceding directions relative to the proper dilution and strength upon the areometer answer best; some distillers, however, in addition to the alcohol, extract the alkaline salts, chiefly potassa, and in this case the preceding strength of 8° on the areometer would offer an inconvenience, inasmuch as a large amount of fuel would be consumed in evaporating the residuary liquid after the alcohol was expelled. To prevent such expenses for combustibles, an investigation was instituted to find out a means for fermenting the saccharine wash at a greater density than 8°, and the endeavor turned out successful. The high density is 14° of the areometer, and, in order to ferment such a solution without its passing to the acid fermentation, the following mode is adopted:—When a sweet wash of 14° B. is set to ferment, the temperature of the liquid rises to 30° C. = 86° Fahr. in twenty-four hours, at which degree the alcohol is readily transformed into acetic acid. To oppose the formation of acetic acid, from the high temperature already mentioned, it is necessary, as soon as the liquid marks 27° C. or 76·6° Fahr., to divide it into two equal portions, and add to each half as much molasses of 14° strength as it already contains. Previous to mixing the second portion of molasses with the fermenting liquor, they should be well agitated with two per cent. of their weight of barm. Fermentation is now allowed to proceed without apprehension of the temperature rising so high as to favor the acetous fermentation in the liquor.

M. **Laugier's** apparatus, which will be subsequently described, is expressly adapted for the distillation of fermented saccharine liquors, but wine or malt wash may also be distilled in it. It works upon the same principle as **Derosnes'** still, under a simpler construction. In France, where considerable quantities of molasses are converted into rum, and this apparatus is in operation, the distillery is divided into the store-room, where the stock of molasses is retained until required for use; the fermentation-room, which occupies another compartment; the stills a third; and the store-room for the finished spirit a fourth.

Several fermenting tuns are furnished of a size to correspond with the quantity of wash which the still is capable of working daily, and these tuns are worked in rotation, so that one may be worked off and ready for distillation each day; by this means the fermented liquor is prevented from being exposed to the air, and the formation of acetic acid wholly prevented.

A side view of the apparatus, as it appears set in brickwork, is seen in Fig. 79; A and C are sectional views of the boilers heated by the fire, *c*, under A, round which the flue passes; thence in the direction of the arrows round the second boiler, C, in a similar way, and afterwards into the chimney; G is the rectifying cylindrical vessel, and E the refrigerator where the spirit is condensed. The boiler, A, is furnished with two pipes; one of these is for discharging the contents when all the alcohol is expelled, and is furnished with a stopcock, *f;* the other pipe, *i i*, carries off the generated vapors to the next boiler, C, where it terminates in a perforated rose, within a short distance of the bottom of the vessel.

A pipe issuing from the bottom of C, and furnished with a stopcock, *j*, enters the first boiler, and terminates like the pipe, *i*, in a perforated rose, as seen at *k*. From C, the pipes, *m*, *n* and *l*, rise; *m* and *n* are connected with the rectifying apparatus in the cylindrical vessel, G; the former carries off the vapors generated in C, and the latter returns the liquid condensed in this vessel into the boiler. The pipe, *l*, serves to charge the boiler, C, from the rectifying apparatus. Two pipes, *o o* and L, unite the rectifier and the condenser; the former conducts the uncondensed vapors from the rectifier to the worm in the refrigerator, and the latter serves to replenish the vessel, G, with liquor from the refrigerator. The pipe, L, descends to within a short distance of the bottom of G, so as to have the colder liquid issuing in contact with the pipes which contain the warmer vapors. Another pipe, *p*, emerging from the cover of the rectifying vessel, conducts any vapor generated by the condensation in part of the distilled products of the boilers, A and C, to the condenser. The refrigerator is filled through the funnel tube, *t*, from the tank, *v*, by means of the pipe and stopcock, *u*. The manner of working the still is simple:—Liquor is allowed to enter the funnel tube, *t*, until it begins to flow down the pipe, *l l*, into the boiler, C; and as soon as this is observed, the stopcock, *j*, is opened, and the liquor admitted into the first boiler, until it rises a few inches above the rose, *k*, as shown by the glass gage, *g g;* the stopcock, *j*, is shut, and the liquor allowed to flow into C, until it rises above the end of the pipe, *l l*, which emerges into the liquor; this is shown by another gage pipe, *g′ g′*, attached to C. The stopcock, *u*, is now closed, and the fire urged under the first boiler, the contents of which very soon boil, and are partly converted into vapor, which is emitted to the next boiler through the pipe, *i i*. By means of the caloric abstracted from the vapor in passing through the liquid, and the heat communicated to the boiler by the flue which circulates round C, the contents of this vessel are also made to boil, and, like those of A, are partly vaporized; the vapor is forced through the pipe, *m*, into the rectifying vessel, where, by means of a peculiar arrangement of pipes—to be explained further on—the greater part of the watery vapor which is forced along from A and C is condensed, and falls back into the boilers through the pipe, *n*, to undergo a second distillation. The first portions of the vapor that enter this vessel are entirely condensed, in consequence of the liquid contained in it being as yet cold; but when, after a short time, the latent heat of the condensing vapor raises the temperature of this liquid so high that it will not condense any longer the richer alcoholic vapor, the latter rises through the pipe, *o o*, and enters the worm in the vessel, E, where complete resolution takes place, and the spirit produced flows out by the pipe, *q*. As soon as the liquor in the first boiler becomes exhausted, the fire is slackened for a short time, the contents discharged through the pipe and stopcock, *f*, and a further quantity admitted by the pipe and stopcock, *j*, from the boiler, C, and this again replenished by opening the stopcock, *u*, of the tank, *v*. The fire is again urged briskly, and thus the distillation proceeds successively, so as not to lose alcohol.

Fig. 79. Fig. 80.

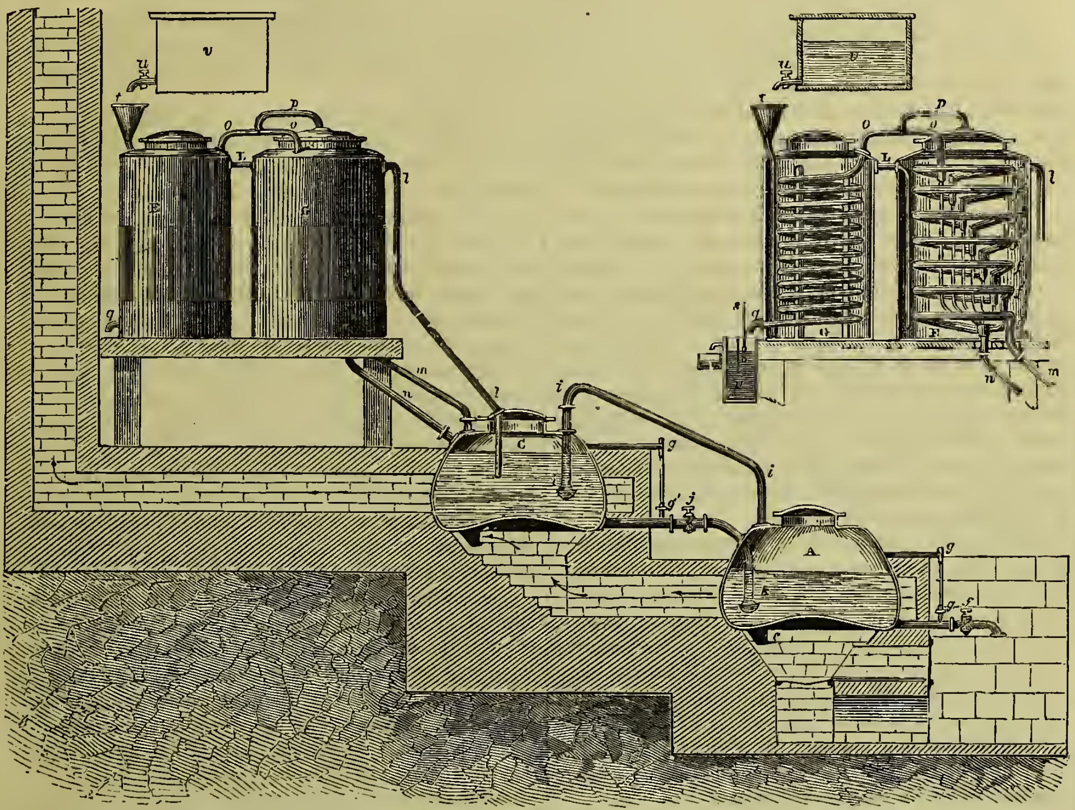


Fig. 80 is a section of the rectifier and refrigerator: in the first there are seven compartments formed of large circular pipes, as seen at $f\ f'\ f''\ f'''\ f^5\ f^6\ f^7$, each one of which terminates in a smaller pipe that meets the others in a ball at the end of the pipe, *n*. *oo* shows the connection of this apparatus with the refrigerating worm in the vessel, G; *p*, the pipe connected with *o o*, and emerging from the cover of the vessel, E, for the purpose of carrying off any vapors generating in the liquid surrounding the apparatus in this vessel. *t* is the funnel pipe, reaching to the bottom of the refrigerator; and *q* the termination of the worm, by which the finished spirit is discharged into a small covered vessel, *r*, which contains an alcoholometer, *s*, to indicate the strength of the spirit.

The fermenting molasses are so viscous, when they are treated in such a way as to mark only 8° of the areometer, that at some periods the mixture intumesces, so as to overflow the fermenting tuns, unless the latter be very large. To obviate this, some soft soap is added, which being partly decomposed by the little excess of acid contained in the liquid, the oily portion forms a layer which destroys the homogeneousness of the sirupy effervescence, and disposes the bubbles of carbonic acid to burst and pass off without much rising in the liquid. Fermentation is known to be finished when the action, after having been regularly increasing, ceases suddenly, and the temperature subsides; another sign by which a good fermentation is distinguished, is the falling in of the head, and the diminution of specific gravity, from 8° to 1°.

If the liquid, after attenuation, be not immediately distilled, it is necessary to cool it down rapidly, to prevent its being converted into acetic acid. This is done either by passing cold water through a coiled pipe in the fermenting tun, or by emptying the whole into sulphured tubs, which resist the further action of any fermentation. Of these two, the worm is preferable, as in a slow fermentation the transmission of hot water through this pipe would revive it; and when the temperature of the liquid becomes higher than what it should be, from a too rapid fermentation, it is equally opposed by pouring cold water through the worm. LAUGIER'S apparatus is best adapted for the distillation of the fermented liquor of molasses.

The quantity of spirit obtained from molasses when fermented at 14°, is less than when the mash is made to mark 8°; but considering the advantage of obtaining the alkaline matter there is less evaporation, and, consequently, less fuel consumed. A method has been lately introduced by DUBRUNFAUT, by which the attenuation is made at 8°, and the saline matter obtained without much extra fuel. One part of this process is to employ the spent liquor after distillation, for bringing a second portion of molasses to 8° of the areometer; this liquor has no injurious effect upon the fermentation, and offers the advantage of having double the quantity of salts in the same bulk of liquid.

This liquid he introduced into a steam boiler instead of water, for the purpose of generating steam to heat the liquid for distillation, and the apparatus. Finally, the evaporation is finished in three pans or boilers, which are partly heated by the waste caloric from a reverberatory furnace at the end, wherein the saline mass is torrefied. The degree of strength which the liquid has, before it is run into the furnace, is 32°. One thousand kilogrammes of molasses afford from one hundred to one hundred and forty kilogrammes of saline matter, marking 50° to 55° on the alkalimeter.

POTATO SPIRIT.—Potatoes afford a considerable quantity of alcohol; and of late years the manufacture has been extensively conducted in France. There are two methods practised: in the first, the starch of the potato is fermented without any previous preparation, and in the second, the starch is converted into sugar by sulphuric acid. If a quantity of starch, no matter whether obtained from wheat or potatoes, be boiled with water acidulated with sulphuric acid, incessantly, during a few hours, occasionally adding water as it evaporates, to preserve perfect fluidity; then saturating with lime—continuing the boiling, after separating the sulphate of lime, until the solution be concentrated—a dark sirupy liquid is obtained, which, on cooling, affords abundance of sugar in crystals. This sugar certainly differs, in some respects, from common sugar; it is not quite so sweet, nor so soluble in water; it crystallizes differently, fuses at a much lower heat, and its solution ferments without the addition of yeast. It has been found that, during the whole process of its formation, not a bubble of gas is discharged; that the sulphuric acid remains unchanged, and that the contact of air is unnecessary. These facts afford additional proof that starch and sugar are the same in composition, and that the conversion is effected by some unknown agency of the sulphuric acid in altering the mode of combination in which the carbon, oxygen, and hydrogen are held together. One hundred parts of starch produce about one hundred and ten parts of sugar, which is converted by fermentation into alcohol. The advantages afforded by converting potatoes to this use, are, that they are cheap, and afford a good spirit, while the residuum of the distillation is good food for cattle; grain is economized, and less yeast is consumed.

To obtain spirit according to the first process, the potatoes are to be well steamed for an hour, and then bruised between two cylinders of wood or sandstone Ground malt is to be mixed in a keeve with warm water, in quantity sufficient to give the consistence of thin pap, and the potato paste is then added, the whole well stirred with a proper quantity of water until no lumps remain. The stirring is to be renewed at intervals, until the mixture is cold. Natural yeast of beer, or that made artificially from rye, is introduced, but in less quantity than would be required for corn, since potatoes ferment more easily. Experience has proved that the addition of red beetroot or carrots to the potatoes and malt, affords spirit of a better flavor, and in larger quantity. When the fermentation has been pushed to its utmost, the whole matter, both liquor and sediment, is to be introduced into the still, and distilled as in any other case, taking proper precautions to prevent burning.

The process recommended by M. SIEMEN, and now applied in Denmark, is to heat three or four tons of potatoes in steam, a little above 212°, then to mash them well by the rotatory motion of an iron cross in the same vessel wherein they are steamed, and to add hot water, alkalized with a pound and a quarter of caustic potassa. All the mucilage which, in the boiled potatoes, commonly remains insoluble, is by the addition of the alkali converted into a starch, which easily passes through the sieve, leaving the thin skin of the potato. The water is to be in such quantity as to form a thin paste; this being quickly cooled, yeast is added, and the process conducted in the usual manner. It is said, that by this method the quantity of spirit from a given weight of potatoes is greatly increased. Fifty hectolitres, thirty litres—137·64 imperial bushels—of potatoes, along with eight hectolitres—22·12 imperial bushels—of ground malt, yield nine hectolitres—198 imperial gallons—of spirit. CADET states that eight hundred pounds of potatoes will afford thirty pounds of spirit, which at that time he calculated to cost the distiller thirty-six francs, and to sell for forty-eight.

The process for procuring alcohol from potato sugar needs not be particularly described. The sugar being once obtained from potato starch, it is easy to conduct the fermentation. During the conversion of the starch into sugar, a few drops of a solution of iodine in alcohol is frequently added to a small portion of the liquor, to see if the blue iodide of starch is formed; this reaction manifests itself as long as any undecomposed starch remains. From fifty kilogrammes—110·31 pounds avoirdupois—of potato starch, converted into sugar by sulphuric acid, are obtained from twenty to twenty-five litres—4·4 to 5·5 imperial gallons—of alcohol, at 0·935.

Vauquelin, who examined forty-seven kinds of potatoes, says that the quantity of starch in one hundred parts varies from twelve to twenty-four parts—the average result was found to be from seventeen to nineteen per cent. According to Wunrich, starch requires but one or two per cent. of sulphuric acid to convert it into sugar, if the heat applied be a few degrees above 212°; and two or three hours are then sufficient to crystallize it. He applies steam heat in wooden vessels.

During the last runnings of the fermented starch of potato, when under distillation, an oil is obtained, which was examined by Pelletan, and which he supposed to resemble the oil procurable from corn spirit. The two oils are, however, materially different.

The yeast thrown up by potatoes during fermentation, even with one-fifth of their weight of barley, possesses but little energy, and is, therefore, not used in attenuating the potato wash.

In the experiments made under the personal inspection of Professor Oersted at Copenhagen, from sixteen and a half to seventeen quarts of spirit, at 50° of Tralles' alcoholometer, were obtained from a ton of potatoes, making a fair allowance for that portion of the product due to the malt used in the maceration. This spirit is stated to have had a good flavor, though the produce was inferior to that obtained by the French chemists. Muller asserts that an apparatus on Siemen's principle, the expense of which is about two hundred and fifty Prussian dollars, is capable of producing fifty per cent. more spirit from potatoes than the apparatus generally used in Germany, calculating from the price and produce of potatoes and rye in 1820. He further adds, that a hundred-weight of the former converted into spirit produces a profit of from five hundred to six hundred rix-dollars, while the same space of ground that produced it, if sown with rye, would not give more than from ten to twelve rix-dollars.

About the year 1832, a gentleman visited the distillery of Messrs. Calder at Eyemouth, in Berwickshire, and found that they had worked for some short time from potatoes. He considered the spirit—which had the flavor of hollands—to be pure and good; and although it was affirmed that no grain or malt had been used, he strongly suspected the contrary. The fermentation was described as beautiful, the head rising seven or eight feet like clouds of cotton; and when beaten down to the surface of the worts, it rose again in the same majestic manner. The gravity worked at was 40°, and the attenuation was good. The potatoes were ground in a mill, like a common pepper-mill in shape, but made of sheet-iron perforated like a grater. The pulp, thus produced, was mashed in the keeve with boiling water, and the extract ran off quite pure, and freely. A sperge, or small worts of about 20° gravity, was obliged to be used, otherwise the worts at the noticed gravity of 40° could not be got off; the produce was good, as there was no deficiency. The spirit sent to the London market, when called grain spirit in the permits, was highly prized; when this error was corrected, and the product was denominated spirit distilled from potatoes, the price fell, and it was not so much in vogue. About the same time, Mr. Jamieson of Fairfield, near Enniscorthy, commenced distilling from potatoes. They were sliced, dried on a corn-kiln, ground to flour, mixed in certain proportions with grain, and mashed in the ordinary manner. But the manufacture was abandoned, in consequence of the opposition of the peasantry, through fear of a scarcity in the article of food.

From some late experiments, Dubrunfaut proposed to brew from the starch of potatoes an excellent beverage resembling French beer, the starch being macerated and fermented with hops. By fermenting the saccharized starch with honey instead of hops, a palatable liquor was made, having all the qualities of Louvaine beer. Potato starch, being free from any peculiar taste, seems capable of receiving flavor in its fermentation from any substance that gives repute to beer, or home-made wines. Dr. Hare, having observed a strong analogy between the saccharine matter of the sweet potato and molasses, or the saccharum of malt, boiled a wort made from the potatoes, of 1060° specific gravity, with a proportionate quantity of hops for the space of two hours. It was then cooled to about 56°, and yeast added. As far as could be judged, the phenomena of the fermentation and the liquor produced, were precisely the same as if malt had been used. The wort was kept in a warm place until the temperature was 85° Fahrenheit, and the fall of the head showed the attenuation to be sufficient; yeast subsequently rose, which was removed by skimming. A further quantity of yeast was precipitated by refrigeration, from which the liquor being decanted, became tolerably fine for new beer, and resembled in flavor ale made from malt. It has been computed that five bushels of potatoes would produce as much wort as three bushels of malt, while the residue, as food for cattle, would be worth half as much as the potatoes.

In the opinion of some—particularly those who have not employed sulphuric acid in saccharifying the starch—the best time to use potatoes in distillation is in spring, when they begin to vegetate. The growth of the buds must be checked, as in the process of malting; and this is easily done by spreading them on a floor, and by subsequent turning, so as to deprive them of as much of their water as possible. When reduced to a pulpy consistence, diluted with boiling water, and drawn off and cooled to a proper temperature, the liquid is then fermented in the same manner as grain worts; and such has been the treatment observed by many who have tried the distillation of potatoes in this country. Sprouted potatoes produce as perfect farina in July as in December, and equal in quantity to what they would have yielded earlier in the season, being, according to Sir John Sinclair, about fourteen pounds per hundred-weight.

It has been stated that potato apples give, by proper treatment, as much alcohol as an equal quantity of grapes, when bruised and fermented with one-eighteenth or one-twentieth of their weight of yeast.

From these details on the application of potatoes in the manufacture of spirit, persons may be induced to try experiments that might ultimately prove advantageous. If they proceed by reduction of the farina to a pulpy substance, the operation is simply by boiling; if by the production of starch, it may be mechanically effected at little expense and labor, either by pounding or grating, and elutriation with cold water. In some parts of France, the tuber of the Jerusalem artichoke —*Helianthus tuberosus*—has been used for the purpose of distillation. The wash extracted from this vegetal, when fermented in the ordinary way, is found to yield a very pure and strong spirit, which is said to resemble that obtained from the grape, more than any other substitute that has hitherto been tried.

The root grows luxuriantly almost in every climate, but it does not appear that it has been cultivated much in England, either for the production of spirit or other uses; it might be remunerative in this particular, in producing a medium beverage between genuine French brandy, and the fiery spirit extracted from grain, and sold under the denomination of gin and whisky.

ARRACK, contracted into RACK, is a spiritous liquor from the East Indies. The name is said to signify, in the East, any alcoholic liquor; but that usually bearing this name is *toddy*, a liquid distilled from the juice of the cocoa-nut tree—*cocos nucifera*—procured by incision. In all countries where rice is abundant, an alcohol is drawn from it, called *arrack* or *rack*. Goa and Columbo arrack are always made from toddy; Batavia and Jamaica arrack from molasses and rice, with a little toddy. The Pariah arrack contains *cannabis sativa* and a species of *Datura*, which render it more inebriating and hurtful; it is not, however, certain, whether the Pariah arrack is used generally to imply a sophisticated spirit, or is only applicable to that liquor with which the above ingredients have been compounded.

The process is nearly the same as for making grain spirit. Rice is put into a vat, covered with water, and agitated to cause it to pullulate. A handful is, from time to time, taken from different parts of the vat, and if the half at least has not pullulated the germination is allowed to proceed, or the fermentation may be hastened by adding lukewarm water, and drawing a certain quantity from the top, heating and returning it to the vat, the contents of which are well stirred. Great caution is necessary in the operation, for, if rummaged too quickly, much risk is run of breaking the seed, which would make the rice decay, and thus hinder the fermentation of the rest. If such a thing occurs, the injured grain might be extracted, but this would be attended with so much labor, as compared to the value of the rice, that the whole is rejected by distillers, and sold for the use of cattle. To avoid these mishaps, a man accustomed to the work is employed. He introduces the rake just below the surface of the rice, agitates the water in turning, and stirs gently till he reaches the bottom; the same caution is observed in bringing the rake again to the surface. When the rice is nearly or half germinated, the plug at the under part of the vat is withdrawn to let out the water; the rice is then removed to a room, and heated like the barley in the distillation of the grain spirit. It is submitted to a heat of 59° Fahr., which finishes the germination.

The subsequent operations are the same as those pursued by the brewer. When the rice has sufficiently acquired the vinous fermentation, it is introduced into the alembic or still, like the other substances discussed.

MOREWOOD was favored, by a gentleman many years resident in India, with several curious remarks upon the kind of stills employed, and the methods pursued. When the material for distilling—whether rice, or the simple fermented juice of the *cocos nucifera*—is ready, a hole is dug in the earth, suited to the size of the still to be used; and, on a level with the bottom of this hole, there is an underground communication made for the purpose of feeding the fire with atmospheric air; near the edge of this orifice is a chimney, serving two purposes—for the supply of the fuel, and for the escape of the smoke; a fire of dry wood is first lit, and, when the ground is completely heated, the still is fixed in it, and so bound round with earth, as to prevent the escape of any caloric. When ebullition commences, and the steam begins to ascend, an Indian pours a gentle stream of water upon the head of the still, or on the broad and thin surface of a plate of tin or copper, with a gutter for the water to run off, which is fixed on a pan, with a hole in the bottom, luted to the neck of the still, and serving as a condenser. The extreme cold produced by the evaporation of the water on so broad a surface, occasions the vapor from the still to be immediately condensed, and to flow in a trickling stream into the receiver.

A lady who resided in India thus describes the working of a native still which she had an opportunity of seeing:—The still was simply constructed: round a hole in the earth, a ledge of clay, four inches high, was raised, with an opening half a foot in width, for the purpose of supplying fuel. Upon the clay a large earthen pot was luted; to its mouth was closed with lute the mouth of a second pot; and where they joined, an earthen spout, a few inches long, was inserted, which served to let off the spirit condensed in the upper jar, the latter being kept cool by a person pouring water constantly upon it. In the cottage, or still-house, was a woman employed in cooling the still by pouring water on it from a cocoa-nut shell ladle. The woman said that she sat at her occupation from sunrise to sunset, without scarcely a change of position, while her husband constantly brought toddy for distillation.

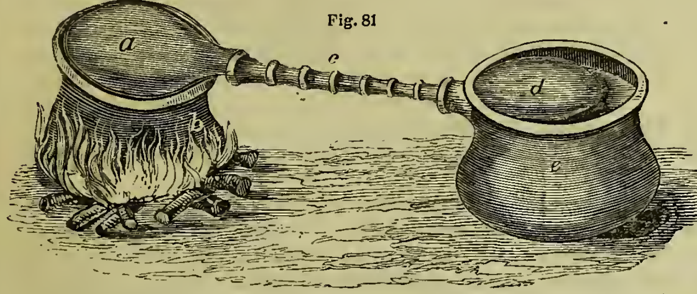
Arrack is drunk in Siam; but its consumption, as well as its facture, is confined to the Chinese resident in that country. It is stated that the privilege for its distillation brings to the government fifty-eight thousand pounds per annum, for the whole kingdom. The greater portion of arrack is distilled at Bankok, the capital; and the remainder at thirteen of the principal towns.

A strong kind of arrack, possessing an unpleasant smell, is distilled from palm wine, *et cetera;* this spirit is called *vellipatty;* another sort is known under the name of *talwagen*. The revenue arising from arrack, in Ceylon, is very large; in the land-rents are included the duties on cocoa-nut trees, which exceed those on rice by nearly fifteen thousand pounds annually.

Arrack, from time immemorial, has been a common beverage among the Cingalese, but as yet their method of manufacturing it is rude, indicating a great want of chemical skill.

The still they employ is of earthenware, and of the simplest construction; the subjoined is, on the authority of MOREWOOD, a true representation of the one in general use:—

Fig. 81



a, *b*, are the capital and alembic luted together; *d*, *e*, a receiver and refrigerator, of one piece, the former connected with the head by a bamboo, *c*.

Ardent spirit is manufactured in much larger quantities in Java than in any other island in the Indian ocean, which may, no doubt, be accounted for by the great industry of the Dutch, and the celebrity which the Batavian arrack so early acquired under their patronage. According to Sir THOMAS RAFFLES, the annexed is the manner of making it:—About seventy pounds of *ketan*, or glutinous rice, are filled up in a small vat; round this heap one hundred cans of water are poured, and on the top, twenty cans of molasses; after remaining two days in this vat, the ingredients are removed to a larger vat adjoining, when they receive the addition of four hundred cans of water and a hundred of molasses. Thus far the process is carried on in the open air. In a separate vat within doors, forty measures of palm wine, or toddy, are immediately mixed with nine hundred of water, and one hundred and fifty of molasses, both preparations being allowed to remain in this state during two days. The first of these preparations is carried to a still larger vat within doors; and the latter, being contained in one placed above, is poured upon it through a hole bored for the purpose near the bottom. In this state, the entire preparation is allowed to ferment for two days, when it is poured into small earthen jars, containing about twenty cans each, in which it remains for the further period of two days, and is then distilled. The proof of a sufficient fermentation is obtained by placing a lighted candle or taper about six inches above the surface of the liquor in the fermenting vat; if the process be properly advanced, the carbonic acid rises and extinguishes the light. Another mode of apportioning the materials for the making of arrack is,

62 parts molasses,
3 do. toddy,
35 do. rice,

which yield, on distillation, twenty-three and a half parts of proof arrack. The stills are made of copper, and are much like those used in the West Indies; the worms consist of about nine turns of Banca tin. The spirit runs into a vessel under ground, whence it is poured into proper receivers, and is called the third, or common sort of arrack, which by a second distillation in a smaller still, with the addition of some water, becomes the second sort; and by a third operation, is what is called the first sort. To ascertain the strength of the spirit, a small quantity of it is burned in a saucer, and the residuum measured; the difference between the original quantity and the residuum gives the measure of the alcohol lost. The completion of the first sort does not require more than ten days, six hours being sufficient for the original preparation to pass through the first still. The Chinese residents, who conduct the whole of this process, call the third, or common sort, *sichew;* the second, *tanpo;* and the first, *kiji.* The latter two are distinguished as arrack *api.* When cooled, it is poured into large vats in the storehouses, where it remains until put into casks. The making of arrack is distinct from that of sugar, which is manufactured to a great extent in Java. The arrack distillers purchase the molasses from the sugar manufacturers.

A very large quantity of arrack is consumed in the East; seven hundred thousand gallons are annually exported from Ceylon, of which upwards of thirty thousand come to England.

CARROT SPIRIT.—In the Transactions of the Royal Society of Edinburgh, is a paper by Dr. HUNTER and Mr. HORNBY, in which they give the details of the process for the production of the above spirit. With the paper was sent a sample of the spirit, and the Society appointed Dr. BLACK, Dr. HUTTON, and Mr. JAMES RUSSELL, to investigate this account, together with the specimen of the spirit, and to report upon the same, which they did as follows:—

The sample of spirit which was sent by Dr. HUNTER, of York, to the Royal Society, has been examined, and also the account of the experiment on the fermentation and distillation of carrots, by which the spirit was produced. The experiment was made by Mr. THOMAS HORNBY, druggist in York, with one ton and eight stones of carrots, which, after being exposed to the air a few days to desiccate, weighed one hundred and sixty stones, and measured forty-two bushels; they were affused with water, topped, and tailed, by which they lost in weight eleven stones, and in measure seven bushels; and being then cut, were boiled with the proportion of twenty-four gallons of water to one-third of the above-mentioned quantity of carrots, until the whole was reduced to a tender pulp, which was done by three hours' boiling. From this pulp the juice was readily extracted by means of a press, and two hundred gallons of juice were produced from the whole quantity.

The juice was reboiled with one pound of hops for five hours, and then cooled to 66° Fahrenheit, and six quarts of yeast being added, it was set to ferment. The strong fermentation lasted forty-eight hours, during which time the heat abated to 58°; twelve gallons of unfermented juice, which had been reserved, were then heated, and added to the liquor, the heat of which was thus raised again to 66°, and the fermentation was renewed for twenty-four hours more, the air of the brewhouse being all this time at 44° and 46°. The liquor was now turned, and continued to work three days from the bung; lastly, it was distilled, and the first distillation was rectified next day without any addition. The produce was twelve gallons of spirit. It resembled the best corn-spirit in flavor, and was proof. The refuse of the carrots weighed forty-eight stones, which, added to the tops and tails, made provision for hogs, besides the wash from the still, which measured one hundred and fourteen gallons.

From the above, Dr. HUNTER draws the annexed comparison between the distillation of carrots and grain:—

Twenty tons of carrots, which will make two hundred gallons of proof spirit, may be bought for £16. Eight quarters of malt, or rather materials for distillation, consisting of malt, wheat, and rye, may be bought for £16, and will also yield two hundred gallons of proof spirit. The refuse from the carrots will be nine hundred and sixty stones, which, at one penny per stone, will sell for £4. The refuse or grains from the malt, *et cetera*, will be sixty-four bushels, each bushel about three stones, which, at one penny per stone, will sell for sixteen shillings. The Doctor, however, supposes that the manufacture of the spirit from carrots may be attended with more expense than that from malt, but imagines that the greater value of the refuse may compensate for that expense, and that the saving of corn for other purposes is an object worthy of attention and of encouragement.

MILK SPIRIT.—The Tartars and Kalmouks prepare a spirit from the milk of mares or cows, which they greatly relish. Twenty-one pounds of milk yield an ounce and a half of an insipid distillate, and forty ounces of spiritous liquor; the latter, when rectified, gives six ounces of alcohol. OSERETSKOWSKY says that skimmed milk, when deprived of its butyraceous portions, neither produces spirit, *per se*, nor by the addition of a ferment. Secondly, milk retaining a portion of its cream, agitated until it commences fermentation, produces alcohol, but in small quantity. Thirdly, the entire milk kept in a close vessel, which by agitation commences fermenting, furnishes more spirit. Nearly the same amount of spirit is procured from the same milk, when a ferment is added to it. Fourthly, milk deprived of the most part of its caseous matter furnishes very little spirit. Fifthly, when the serous part only of the milk is distilled, it affords little spirit. Sixthly, milk which is fermented in a close vessel, and left for some time, loses its acid, and furnishes much more spirit than it would do if distilled immediately. Seventhly, if the heat of the fermented milk be sustained, the alcoholic portion passes into vinegar.

MADDER SPIRIT.—Within the last few years a patent has been taken out in France by M. JULLIEN, for distilling a spirit from the washings of madder, which were previously allowed to run waste. Several madder distilleries are now established in France, and one has been lately erected in Glasgow, by Mr. J. HINSHAW, of the firm of Messrs. ARTHUR and HINSHAW.

To explain the economy of this remarkable process, it may be stated that the madder is imported into this country in the form of a root, which somewhat resembles liquorice, or the stems of heather. To prepare it for the dyer, and especially for dyeing the celebrated turkey red—which has long been a staple business in Glasgow—the root is first roasted, or kiln-dried; it is then ground into a coarse powder by two large cylinders of stone, revolving in a vertical position, like those used for crushing linseed-cake; in this state it is washed and subjected to hydrostatic pressure, to free it from the saccharine and other matters which would injure its dyeing qualities. When properly washed, it is again dried, and submitted to the action of another pair of stone cylinders, until it is reduced to an impalpable powder.

The washings of the madder at the dye-stuff factory of Messrs. ARTHUR and HINSHAW were formerly permitted, as in other establishments, to flow into the nearest canal, or other reservoir of refuse; but now it is carefully preserved, and distilled into a strong spirit, which, although more volatile and less agreeable to the taste than that distilled from malt or raw grain, may perhaps be found equally useful for various manufacturing purposes.

The process of the fabrication is exceedingly simple: mere washing of the madder supersedes the mashing of the grain or malt in common distilleries. The root being dried and ground, as already stated, is mixed in a series of vats with the requisite proportion of cold water, or water at the ordinary temperature. These vats are three feet deep by five or six in diameter. The mixture is effectually rummaged by the workmen with instruments resembling large hoes, the madder being kept in a state of diffusion in the liquid until it is conceived that the saccharine matter is entirely extracted. The liquor is then drawn off by sluices, and the vats being lined with coarse cloth, it percolates through that medium as a filter, leaving the madder behind, to be again carefully collected, dried, and finally ground for the use of the dyer.

When the madder liquor, or worts, is drawn off, it is let into a kind of under-back, from which it is immediately pumped up into a large fermenting tun. Two tons of madder are found in practice to yield two thousand five hundred gallons of liquor, or madder worts, of a density equivalent to 30° by Allan's saccharometer.

The fermenting tun being filled by the produce of several washings, has usually begun to ferment before it receives the liquor from the last washings. It is not a little remarkable, that this fermentation of the madder liquor commences and proceeds spontaneously, without the addition of yeast, or the application of heat. No ferment of any description is added, and the water used throughout the entire process, up to the point of distillation, is at the ordinary temperature. The addition of yeast has been tried, but without any sensible advantage, either in promoting the fermentation, or increasing the ultimate yield of spirits. In consequence, however, of this spontaneous character of the process, the fermentation is slower than usual, averaging from six to eight days to bring the worts to a proper attenuation. This is conceived to be accomplished when the gravity of the worts is reduced from 24° to 12°.

From the fermenting tun the wash is immediately run into the still, and the rest of the operation proceeds as in the distillation of malt or raw grain whisky. The still used is STEIN'S patent, and is somewhat similar to COFFEY'S, but rather more complex in its arrangements, and possessing the undoubted advantage that it may be applied, with equal efficiency, either to the distillation of malt or raw grain whisky. From this still the madder spirit is drawn off at one operation; it may be run weaker or stronger, but is generally taken from the still about 60° to 64° over proof by SYKES' hydrometer.

The produce from two tons of madder, yielding, as has been stated, two thousand five hundred gallons of liquor at 30°, is about sixty gallons of spirit.

The madder distillery at Glasgow, to which the preceding details more especially refer, has only been a few months in operation, and, therefore, the ultimate success of the experiment cannot yet be decided. The high duty on spirit in this country places it under a great disadvantage, compared with the French distilleries of the same kind. It turns to account, however, for manufacturing purposes at least, an otherwise useless substance, hitherto lost to the community, and, as a remarkable illustration of manufacturing economy, it certainly ought to succeed.

Another New Source of Spirit.—It is stated that the berries of the *Sorbus Aucuparia* are now used in the North of France for the production of spirit, and the result is said to be equal to the purest distillation from grapes for brandy. The berries, when perfectly ripe, are first exposed to the action of cold in the open air, then put into a wooden vessel, bruised, and boiling water poured on, the menstruum being stirred until it has sunk in temperature to 82° Fahr. A proper quantity of yeast is then added, the whole covered and left to ferment. When the action has terminated, the liquor is put into the still, and drawn over in the usual way. The first running is weak and disagreeable in flavor, but being distilled from very fresh finely-powdered charcoal, in the proportion of eight or nine pounds to forty gallons of weak spirit, a very fine product is obtained. The charcoal should remain in the liquid two or three days before the second distillation.

Having given a full account of the different kinds of spirit, the reader must have perceived how much has still to be accomplished for the guidance of those connected in any way with alcoholic liquors. It is to the resources of Chemistry that one must look for such improvements. The chemist first lighted the distiller's path by his researches on the essential oils which communicate to wines, grain spirit, potato spirit, *et cetera*, their peculiar bouquet, and by a prosecution of his labors he procured these compounds in greater abundance. Such discoveries led to the artificial imitation or formation of the rarer and more costly liquors, as cognacs, genevas, and other beverages which, on account of their high price, are attainable only by the affluent. It is to be regretted, however, that those engaged in manufactures, for the proper management of which there is hourly required an intimate acquaintance with the several reactions of bodies, and the various changes to which they are subject, are so far ignorant of the general properties of even those very substances which are daily passing through their hands, that it is not uncommon to find many who know nothing of the nature of their products beyond the mere name. The consequence of this want of scientific knowledge in the seats of art, and with the owners or conductors of factories, is, that in many instances the most palpable incoherency is shown in the methods adopted; a fact manifested in the inferiority of some of the industrial products of this nation at the Great Exhibition. Successful competition or results, in any fabrication, can only be attained by attentive study; indeed, by making manufacturers students of science. Without chemistry, a process connected therewith, how trivial soever it may be, cannot prosper; and this being admitted, it is surprising and even deplorable that the archives of science are not oftener consulted by persons daily witnessing the triumphs that emanate from this prolific source; instead of doing so, many assert that chemistry is of no use to them—that they look to *practice* for improvements and advantages—in fact, they are ready to reject it *in toto*, as being nothing better than a visionary speculation of some few dreaming theorists. No one will, it is presumed, impugn the fact, that what is often attributed to practice is really the result of a long investigation; and further, that the advances made at a considerable, or rather incredible sacrifice of capital and labor, in the course of centuries, may be superseded by purely theoretical studies in a single day. In truth, most of those who speak disparagingly of scientific and theoretical research are, though strangely inconsistent, ready to acknowledge the benefits conferred upon many branches of industry by chemical discoveries.

From scientific inquiries, even the distillers and rectifiers of spiritous liquors have gathered a rich harvest of experience, inasmuch as they have been made better acquainted with the nature of their operations, and more qualified to procure artificially any beverage almost instantaneously. But many of this class, much to the detriment of their business character, pass by chemistry entirely; the consequence of which is, that in the fabrication of artificial liquors a most absurd course is often adopted, and mixtures used, in favor of which there is neither the evidence of reason nor of common sense.

ALCOHOLOMETRY.—This is the process for ascertaining the centesimal quantity of anhydrous alcohol in a spiritous liquid. It is invariably accomplished by determining the specific gravity of the liquid, but then it is absolutely necessary that only alcohol and water should be present. The quantity of alcohol in spirit containing much volatile oil or saccharine matter, *et cetera*, cannot, therefore, be at once found by their specific gravity.

With the view of being able to calculate the absolute alcohol included in a spiritous liquid from its specific gravity, it was deemed advisable to mix anhydrous alcohol and water in the different proportions, and by experiments, to establish, with certainty, the specific gravity of these mixtures. Such experiments have been gone through at distinct periods; the most accurate and complete were those performed by GILPIN. From GILPIN'S conclusions, aided by results of his own, TRALLES constructed the tables appended.

The per centage of absolute alcohol may be stated by one of two methods; namely, by weight or volume. Liquors being vended by measure and not by weight, the centesimal amount by volume is usually preferred. But as the bulk of liquids generally, and particularly that of alcohol, increases by heat, it is necessary that their reputed richness should have reference to some normal temperature; this standard, as fixed by TRALLES in the construction of his tables, is 60° Fahr.

By weight the per cent. remains the same at all temperatures, while the per cent. by volume varies with the temperature of the liquid; and this entails the necessity of having the sample, in the course of being tested, reduced to the standard degree of the table by calculation or otherwise. In the subjoined, water at its maximum density is taken as the standard for specific gravity, and is put as 1·000, which, at 60° Fahr., equals ·9991.

TABLE I.

Per cent. of alcohol, by volume.	Spec. grav. of the liquid at 60°.	Difference of the spec. gravs.	Per cent. of alcohol, by volume.	Spec. grav. of the liquid at 60°.	Difference of the spec. gravs.
0	0·9991		51	0·9315	20
1	9976	15	52	9295	20
2	9961	15	53	9275	20
3	9947	14	54	9254	21
4	9933	14	55	9234	20
5	9919	14	56	9213	21
6	9906	13	57	9192	21
7	9893	13	58	9170	22
8	9881	12	59	9148	22
9	9869	12	60	9126	22
10	9857	12	61	9104	22
11	9845	12	62	9082	22
12	9834	11	63	9059	23
13	9823	11	64	9036	23
14	9812	11	65	9013	23
15	9802	10	66	8989	24
16	9791	11	67	8965	24
17	9781	10	68	8941	24
18	9771	10	69	8917	24
19	9761	10	70	8892	25
20	9751	10	71	8807	25
21	9741	10	72	8842	25
22	9731	10	73	8817	25
23	9720	11	74	8791	26
24	9710	10	75	8765	26
25	9700	10	76	8739	26
26	9689	11	77	8712	27
27	9679	10	78	8685	27
28	9668	11	79	8658	27
29	9657	11	80	8631	27
30	9646	11	81	8603	28
31	9634	12	82	8575	28
32	9622	12	83	8547	28
33	9609	13	84	8518	29
34	9596	13	85	8488	30
35	9583	13	86	8458	30
36	9570	13	87	8428	30
37	9556	14	88	8397	31
38	9541	15	89	8365	32
39	9526	15	90	8332	33
40	9510	16	91	8299	33
41	9494	16	92	8265	34
42	9478	16	93	8230	35
43	9461	17	94	8194	36
44	9444	17	95	8157	37
45	9427	17	96	8118	39
46	9309	18	97	8077	41
47	9391	18	98	8034	43
48	9373	18	99	7988	46
49	9354	19	100	7939	49
50	9335	19			

The third column of this table exhibits the differences of the specific gravities, in order to facilitate the calculation of fractions of per centage for specific gravities intermediate between those stated in the table—the difference in the densities, as given in the third column, becoming the denominator of the fraction, and the variation between the next and greatest specific gravity in the table and that of the liquid in question forming the numerator. To illustrate this method of calculation by an example, let it be supposed that the specific gravity of a liquid was found to be ·9260 at 60° Fahr., which numbers, according to the table, would indicate a per centage of alcohol between fifty-three and fifty-four, or fifty-three and a fraction whose numerator is the difference between ·9275, the specific gravity of an alcohol fifty-three per cent., and ·9260, which difference equals 15; this number forms the numerator of the fraction, whose denominator is the difference between the specific gravities of the liquids containing fifty-three and fifty-four per cent. of alcohol, and which in the foregoing table is 21; hence the value of the liquid, specific gravity ·9260, is $53\frac{15}{21}$, or 53·71 per cent.

The content, by weight, of alcohol in a liquid, the centesimal value of which per volume has been found, is ascertained by a simple calculation. This operation is done by multiplying the content per volume of alcohol into the specific gravity of absolute alcohol, and dividing the product by the specific gravity of the liquid. An example will aid the reader in comprehending the manner of performing the work:—Suppose an alcohol of fifty per cent. by volume, whose density, according to the preceding table, is ·9335. Absolute alcohol in the table is ·7939, and this multiplied by 50, and the product divided by ·9335, gives the per centage by weight, thus:—

$$\cdot 7939 \times 50 = 39\cdot 6950 \div \cdot 9335 = 42\cdot 5227 \text{ per cent.}$$

It necessarily happens that alcoholic liquors are seldom at the very degree of the thermometer at which the preceding table has been drawn up, and as it is difficult to bring the sample to mark 60° Fahr., TRALLES, for the purpose of surmounting this obstacle, constructed another table, wherein the volume of alcohol is given corresponding with the temperature of the liquid at the time of the experiment.

TABLE II.

Per cent., byvolume, of absolute alcohol.	Spec. grav. of the liquid at 60°.	Increase of spec. grav. at the indicated temperature *below* 60°.					
		+ 55°	50°	45°	40°	35°	30°
0	0·9991	4	7	9	9	9	7
5	9919	4	7	9	10	10	9
10	9857	5	9	12	14	15	15
15	9802	6	12	17	21	23	25
20	9751	8	16	23	29	35	39
25	9700	10	21	31	39	48	56
30	9646	13	26	39	51	62	73
35	9583	16	31	46	61	75	89
40	9510	18	35	52	70	87	103
45	9427	19	39	57	76	94	112
50	9355	20	40	60	80	99	118
55	9234	21	42	63	84	104	124
60	9126	22	43	65	86	107	127
65	9013	22	45	67	88	109	130
70	8892	22	45	68	90	112	133
75	8765	23	46	68	91	113	135
80	8631	23	47	70	92	115	137
85	8488	23	47	70	93	116	139
90	8332	24	48	71	94	117	140

TABLE II.—Concluded.

Per cent., by volume, of absolute alcohol.	Spec. grav. of the liquid at 60°.	Decrease of spec. grav. at the indicated temperature *above* 60°.							
		65°	70°	75°	80°	85°	90°	95°	100°
0	0·9991	1	11	17	24	32	40	50	60
5	9919	1	11	18	25	33	42	51	62
10	9857	6	13	20	29	37	47	57	68
15	9802	7	15	25	34	44	55	67	79
20	9751	9	19	30	41	53	66	79	93
25	9700	11	24	36	50	63	78	93	109
30	9646	14	28	43	59	75	91	108	125
35	9583	17	33	50	68	86	104	122	141
40	9510	18	37	56	75	94	114	136	154
45	9427	20	40	60	80	101	122	143	154
50	9335	21	42	63	84	106	128	150	173
55	9234	22	43	65	87	109	132	155	178
60	9126	22	44	67	90	113	136	159	183
65	9013	22	45	68	92	115	138	162	187
70	8892	23	46	69	93	117	141	165	190
75	8765	23	46	70	94	119	143	167	192
80	8631	23	47	71	96	120	144	169	194
85	8488	24	48	72	96	121	145	170	195
90	8332	24	48	72	97	121	146	171	196

A further objection to these tables is, that the specific gravity of the mixtures of alcohol and water at elevated or reduced temperatures is not the *real* but the *apparent* density. The cause of this discrepancy is, that the vessels of glass or copper in which the liquids are weighed are liable to expand or contract with change of temperature, so that the specific gravity of the liquid obtained in this way is only what results from the difference of the expansion of the liquid and of the vessel.

TRALLES constructed a third table, in order that the per centage by volume in an alcoholic liquid might be ascertained from the more uniform arrangement of the numbers denoting the specific gravities.

In Table III. the densities are given of the several mixtures from 30° to 85°, as ascertained by a glass instrument; but these numbers, by the aid of the allowance, as seen in Table IV., can be made to correspond with the indications of a brass alcoholometer.

TABLE III.

Per cent. of alcohol, by volume.	Specific gravity of the liquid, ascertained by glass instruments, at the indicated temperatures.											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
0	·9994	·9997	·9997	·9998	·9997	·9994	·9991	·9987	·9981	·9976	·9970	·9962
5	9924	9926	9926	9925	9925	9922	9919	9915	9909	9903	9897	9889
10	9868	9869	9868	9867	9865	9861	9857	9852	9845	9839	9831	9823
15	9823	9822	9820	9817	9813	9807	9802	9796	9788	9779	9771	9761
20	9786	9782	9777	9772	9766	9759	9751	9743	9733	9723	9713	9701
25	9752	9745	9737	9729	9720	9709	9700	9690	9678	9666	9653	9640
30	9715	9705	9694	9683	9671	9658	9646	9633	9619	9605	9590	9574
35	9668	9655	9641	9627	9612	9598	9583	9567	9551	9535	9518	9500
40	9609	9594	9577	9560	9544	9527	9510	9493	9474	9456	9438	9419
45	9535	9518	9500	9482	9464	9445	9427	9408	9388	9369	9359	9329
50	9449	9431	9413	9393	9374	9354	9335	9315	9294	9274	9253	9232
55	9354	9335	9316	9295	9275	9254	9234	9213	9192	9171	9250	9128
60	9249	9230	9210	9189	9168	9147	9126	9105	9083	9061	9039	9016
65	9140	9120	9099	9078	9056	9034	9013	8992	8969	8947	8924	8901
70	9021	9001	8980	8958	8936	8913	8892	8870	8847	8825	8801	8778
75	8896	8875	8854	8832	8810	8787	8765	8743	8720	8697	8673	8649
80	8764	8743	8721	8699	8676	8653	8631	8609	8585	8562	8538	8514
85	8623	8601	8579	8556	8533	8510	8488	8465	8441	8418	8394	8370
90	8469	8446	8423	8401	8379	8355	8332	8309	8285	8262	8238	8214

TABLE IV.

To be subtracted.						To be added.					
30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
·0005	·0004	·0003	·0002	·0002	·0001	—	·0001	·0002	·0002	·0003	·0004

The necessity for using Table IV. arises from the discrepancy in the contraction or expansion of glass or brass at different temperatures, occasioning variation in the density; hence these numbers must be added or subtracted, as directed, according to the temperature, when a brass instrument is employed.

It occurs that liquids are tested whose temperature and specific gravity are intermediate between those instanced in the preceding table, and in this case the corresponding content of alcohol must be found by an inconvenient method of calculation. To give an example:—Let it be supposed that the specific gravity of an alcoholic solution has been found by experiment to be ·9320 at a temperature of 72° Fahr. In the column under 70°, the specific gravity ·9388 is that which is next over the above number, and in the column under 75° the gravity nearest to it is ·9369, both of which exceed ·9320—the former by ·0068, and the latter by ·0049. The difference between these two numbers is ·0019, which is the variation for 5°, or between 70° and 75°, and by dividing by 5, the quotient is $\frac{\cdot 0019}{5}$, the difference for each degree. As the temperature of the liquid under examination is 72°, or 2° over 70°, it is necessary to reduce the specific gravity to what it would indicate were the liquid at 70°, by adding a multiple of $\frac{\cdot 0019}{5}$ by 2, or $\frac{\cdot 0038}{5} = \cdot 0007\frac{3}{5}$ to the specific gravity obtained—·9320—which would make it ·9327$\frac{3}{5}$, or, omitting fractions, ·9327. By referring to the table, will be seen in the horizontal column opposite 45 per cent. of alcohol, and under 70°, the specific gravity

·9388, and in the same column, in a line with 50 per cent. of spirit, ·9294, whose difference from the foregoing is ·0094; thus the variation in gravity at the same temperature, for 5 per cent. of alcohol, is ·0094. In like manner, the difference of ·9388 and ·9327, the reduced gravity for the liquid specified, is ·0061; and since 5 per cent. of spirit has been shown to correspond with ·0094, it is found, by simple proportion, that ·0061 will be equivalent to 3·24 per cent., and this, added to 45 per cent., the spirit in the liquid of gravity next preceding that which is supposed to be ascertained, gives 48·24 as the per centage by volume of alcohol. Numerically—

$$\cdot9388 - \cdot9320 = \cdot0068, \text{ and}$$
$$\cdot9369 - \cdot9320 = \cdot0049.$$

By subtracting the lesser of these from the greater, *videlicet*, ·0068 — ·0049 = ·0019, the difference for the 5° between 70° and 75° Fahr., giving for each degree $\frac{\cdot0019}{5}$; and to reduce the corresponding gravity of the liquid at 72° to that of 70°, there must be added to it $\frac{\cdot0019}{5} \times 2\ (=72-70) = \frac{\cdot0038}{5} = \cdot0007\frac{3}{5}$; and thus one obtains $\cdot9320 + \cdot0007\frac{3}{5} = \cdot9327\frac{3}{5}$, or, omitting fractions, ·9327. Again,

$$\cdot9388 - \cdot9294 = \cdot0094, \text{ and}$$
$$\cdot9388 - \cdot9327 = \cdot0061.$$

And since the former indicates a difference of 5 per cent. in the amount of alcohol, at the same temperature, the equivalent for ·0061 under similar circumstances is obtained by simple proportion, *exempli gratia:*

As 94 : 5 :: 61 : 3·24, which, when added to 45, gives 48·24, the content per cent. by volume of alcohol in the liquid. From all the tables in the foregoing for the determination of the volume of alcohol in a liquid, at whatever temperature it may stand, it is seen that reference is always had to the per centage at the normal temperature of 60° Fahr. Hence, in examining an alcoholic liquid for its true content of pure alcohol, the heat must be diminished to 60°, or else the temperature noted at the time of experiment, and then by calculation reduced to 60°; or the content of alcohol at 60° may be found as in Table II., where the specific gravity at the different temperatures is in inverse proportion to the volume of alcohol.

To avoid this calculation, Tralles calculated another table, which gives the content in volume of absolute alcohol in a liquid, reference being had to the bulk of the liquid at the temperature at which it is measured.

For the prevention of error, it is absolutely necessary to determine the specific gravity of the liquid at the same degree at which it stands when measured; a glass instrument should be employed.

Table V.

To ascertain at any temperature, from the specific gravity, the quantity of absolute alcohol in a liquid expressed in volume centesimally, at the indicated temperature.

Per cent. of absolute alcohol in the liquid as measured.	Specific gravity of the liquid, ascertained by glass instruments, at the indicated temperatures.											
	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
0	0·9994	·9997	·9997	·9998	·9997	·9994	·9991	·9987	·9981	·9976	·9970	·9962
5	9924	9926	9926	9926	9925	9922	9919	9915	9909	9903	9897	9889
10	9868	9869	9868	9867	9865	9861	9857	9852	9845	9839	9831	9823
15	9823	9822	9820	9817	9813	9807	9802	9796	9788	9779	9771	9761
20	9786	9782	9777	9772	9766	9759	9751	9743	9733	9722	9711	9700
25	9753	9746	9738	9729	9720	9709	9700	9690	9678	9665	9652	9638
30	9717	9707	9695	9684	9672	9659	9646	9632	9618	9603	9588	9572
35	9671	9658	9644	9629	9614	9599	9583	9566	9549	9532	9514	9495
40	9615	9598	9581	9563	9546	9528	9510	9491	9472	9452	9433	9412
45	9544	9525	9506	9486	9467	9447	9427	9406	9385	9364	9342	9320
50	9460	9440	9420	9399	9378	9356	9335	9313	9290	9267	9244	9221
55	9368	9347	9325	9302	9279	9256	9234	9211	9187	9163	9139	9114
60	9267	9245	9222	9198	9174	9150	9126	9102	9076	9051	9026	9000
65	9162	9138	9113	9088	9063	9038	9013	8988	8962	8936	8909	8882
70	9046	9021	8996	8970	8944	8917	8892	8866	8839	8812	8784	8756
75	8925	8890	8873	8847	8820	8792	8765	8738	8710	8681	8652	8622
80	8798	8771	8744	8716	8688	8659	8631	8602	8573	8544	8514	8483
85	8663	8635	8606	8577	8547	8517	8488	8458	8427	8396	8365	8333
90	8517	8486	8455	8425	8395	8363	8332	8300	8268	8236	8204	8171

Table VI.

To be added.						To be subtracted.					
30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°
·0005	·0004	·0003	·0002	·0002	·0001	—	·0001	·0002	·0002	·0003	·0004

For the reasons assigned under Tables III. and IV., the numbers in Table VI. must be added or subtracted, as may be deemed necessary, to or from the specific gravities given in Table V., according to the temperature.

From the above tables, the true content of alcohol in a liquor, or *its richness*, may be ascertained by the specific gravity.

It will be as well to consider here the plan pursued for ascertaining with accuracy the specific gravity of the various liquids. Invariably, the density is found by one of two methods—either by actually weighing a portion of the liquor in an accurate specific gravity bottle, or by hydrometer.

The latter is better adapted, as it affords a more expeditious means of finding the density in practice. Various hydrometers are employed, the principal ones being Beaumé's, Sykes', and Dicas', all of which have corresponding tables to indicate the quantities of alcohol according to the gravity. It being thought more convenient and simple to have an instrument which would indicate at once the content of alcohol, one was formed, partly on the plan of the hydrometer, to which the term *alcoholometer* has been applied; it may be made either of glass or brass. **Tralles**, in constructing one of these instruments, has drawn up the annexed alcoholometric table for guidance, which shows, from the portion of the stem immersed in the liquor, the content of alcohol at 60° Fahr.

TABLE VII.

Per cent. alcohol, by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per cent.	Per cent. alcohol, by volume.	Length of immersed part of stem.	Distance between degrees of scale indicating per cent.
0	9		51	735	23
1	24	15	52	758	23
2	39	15	53	782	24
3	54	15	54	806	24
4	68	14	55	830	24
5	82	14	56	854	24
6	95	13	57·	879	25
7	108	13	58	905	26
8	121	13	59	931	26
9	133	12	60	957	26
10	145	12	61	984	27
11	157	12	62	1011	27
12	169	12	63	1039	28
13	180	11	64	1067	28
14	191	11	65	1096	29
15	202	11	66	1125	29
16	213	11	67	1154	29
17	224	11	68	1184	30
18	235	11	69	1215	31
19	245	10	70	1246	31
20	256	10	71	1278	32
21	266	10	72	1310	32
22	277	11	73	1342	32
23	288	11	74	1375	33
24	299	11	75	1409	34
25	310	11	76	1443	34
26	321	11	77	1478	35
27	332	11	78	1514	36
28	344	12	79	1550	36
29	355	11	80	1587	37
30	367	12	81	1624	37
31	380	13	82	1662	38
32	393	13	83	1701	39
33	407	14	84	1740	39
34	420	13	85	1781	41
35	434	14	86	1823	42
36	449	15	87	1866	43
37	465	16	88	1910	44
38	481	16	89	1955	45
39	498	17	90	2002	47
40	515	17	91	2050	48
41	533	18	92	2099	49
42	551	18	93	2150	51
43	569	18	94	2203	53
44	588	19	95	2259	56
45	608	20	96	2318	59
46	628	20	97	2380	62
47	648	20	98	2447	67
48	669	21	99	2519	72
49	690	21	100	2597	78
50	712	22			

In the practical application of the preceding table, when graduating the alcoholometer, it is requisite to have two liquids of a standard strength and temperature.

Distilled water may be one of these, and the other any alcoholic liquor, the per centage of which has been precisely determined, but it is necessary that both should be at 60°. The level at which the instrument stands in each should be scratched on the stem, and the intermediate space accurately divided according to the strength of the liquid. If the alcoholic liquor be forty-nine per cent., and the distance between the point to which the instrument immerses in this liquid and water be divided into $690 - 9 = 681$ equal parts, the addition of twenty-two such parts will indicate the point for fifty per cent., and twenty-three more for fifty-one per cent., and so on, as is seen in the third column in the table. By adding nine such divisions below zero, or the water-level mark, the point is attained from which the numbers in the second column in the table are calculated for each succeeding per cent. of spirit.

In graduating the scale, it would perhaps be more convenient to have two instruments; one to have indications denoting a per centage, say, from one to eighty, and the other from the latter up to pure alcohol. For this end it would, however, be absolutely necessary to adjust the instrument having the higher indications, with two liquids at the normal degree of temperature of the preceding, whose per centage of alcohol should be eighty and a hundred; then, to observe the points to which it sinks in these, and divide the intermediate space into measures corresponding with those in the table.

In constructing one of these alcoholometers, it is necessary to have the stem as uniform as possible, but tubes varying between one-thirtieth or one-twentieth of the diameter may be used. When this alcoholometer is employed, the temperature of the liquid must be at 60°, else the results will be incorrect; for if the degree should differ from the above, the centesimal amount of alcohol cannot be ascertained by taking the specific gravity corresponding with the spirit indicated by the alcoholometer, and, therefore, the true per centage is calculated from this gravity in the usual way, by Tables III. or IV., as in the foregoing.

To dispense with the trouble of such a calculation, **Tralles** devised another table, by which the *real* per centage of alcohol is found in liquids of different temperatures, from the results exhibited by the instrument. This table is given below, Table VIII., and corresponds with Table III. in the preceding.

The numbers in the vertical columns under the temperatures, are the observed degrees of the alcoholometer, and indicate the per centage of the absolute alcohol by volume. If an alcoholic liquid at a temperature of 75° be found to contain 62·9 per cent. by volume, by reference to the table its true per centage at 60° is 60.

Tables IX. and X. following, give the richness per cent. by volume of the liquid at the temperature it possesses when tested. They correspond with Table V. in the preceding, and, like that, it is necessary that the solution should be tested at exactly the same temperature at which it is measured. Table IX. is for a glass, and Table X. for a brass alcoholometer.

TABLE VIII.

To find the true per centage of absolute alcohol by volume, in a liquid at 60°, from the observed per centage indicated by a glass alcoholometer at any other temperature.

30°	35°	40°	45°	50°	55°	60°	60°	65°	70°	75°	80°	85°
— 0·2	— 0·4	— 0·4	— 0·5	— 0·4	— 0·2	0	0	+ 0·2	+ 0·6	+ 1·0	+ 1·4	+ 1·9
+ 4·6	+ 4·5	+ 4·5	+ 4·5	+ 4·6	+ 4·8	5	5	5·3	5·8	6·2	6·7	7·3
9·1	9·0	9·1	9·2	9·3	9·7	10	10	10·4	11·0	11·6	12·3	13·0
13·0	13·1	13·3	13·5	13·9	14·5	15	15	15·6	16·3	17·1	18·0	19·0
16·5	16·9	17·4	17·8	18·5	19·2	20	20	20·8	21·8	22·8	23·8	24·9
19·9	20·6	21·4	22.2	23·0	24·1	25	25	25·9	27·0	28·2	29·4	30·5
23·5	24·5	25·7	26·6	27·7	28·8	30	30	31·1	32·2	33·4	34·5	35·7
28·0	29·2	30·4	31·6	32·7	33·8	35	35	36·2	37·3	38·4	39·5	40·6
33·0	34·2	35·4	36·7	37·8	39·0	40	40	41·1	42·2	43·3	44·3	45·4
38·4	39·6	40·7	41·8	42·9	43·9	45	45	46·1	47·1	48·2	49·2	50·3
43·7	44·7	45·8	46·9	47·9	49·0	50	50	51·0	52·0	53·0	54·0	55·1
49·0	50·0	51·0	52·0	53·0	54·0	55	55	54·9	56·9	57·9	58·9	59·9
54·2	55·2	56·2	57·1	58·1	59·0	60	60	60·9	61·9	62·9	63·8	64·9
59·4	60·3	61·2	62·2	63·1	64·0	65	65	65·9	66·8	67·7	68·6	69·6
64·6	65·5	66·4	67·3	68·2	69·1	70	70	70·8	71·7	72·6	73·5	74·5
69·8	70·7	71·5	72·4	73·3	74·2	75	75	75·8	76·7	77·6	78·4	79·3
75·0	75·8	76·6	77·5	78·4	79·2	80	80	80·8	81·7	82·4	83·2	84·1
80·3	81·1	81·8	82·6	83·5	84·3	85	85	85·7	86·5	87·3	88·0	88·8
85·6	86·4	87·1	87·9	88·6	89·3	90	90	90·7	91·4	92·0	92·7	93·4

TABLE IX.

To find the true per centage of absolute alcohol by volume, in a liquid of any temperature, from the observed per centage indicated by the glass alcoholometer at the same temperature.

True per cent. of alcohol by volume, at 60° Fahr.	Observed per cent. indicated by the glass alcoholometer.										
	30°	35°	40°	45°	50°	55°	65°	70°	75°	80°	85°
0	— 0·2	— 0·4	— 0·4	— 0·5	— 0·4	— 0·2	+ 0·2	+ 0·6	+ 1·0	+ 1·4	+ 1·9
5	+ 4·6	+ 4·5	+ 4·5	+ 4·5	+ 4·6	+ 4·8	5·3	5·8	6·2	6·7	7·3
10	9·1	9·0	9·1	9·2	9·3	9·7	10·4	11·0	11·6	12·3	13·0
15	13·0	13·1	13·3	13·6	14·1	14·5	15·6	16·3	17·1	18·0	19·0
20	16·5	16·9	17·4	17·9	18·5	19·2	20·8	21·8	22·9	23·9	25·0
25	19·8	20·5	21·3	22·2	23·0	24·1	25·9	27·1	28·3	29·5	30 7
30	23·3	24·3	25·5	26·5	27·6	28·8	31·2	32·3	33·5	34·6	35·9
35	27·7	28·9	30·2	31·4	32·6	33·8	36·3	37·5	38·6	39·7	40·9
40	32·5	33·8	35·1	36·5	37·7	38·9	41·2	42·4	43·5	44·6	45·8
45	37·8	39·1	40·3	41·5	42·7	43·8	46·2	47·3	48·5	49·6	50·8
50	43·1	44·2	45·4	46·6	47·7	48·9	51·1	52·2	53·4	54·5	55·6
55	48·3	49·4	50·5	51·6	52·8	53·9	56·1	57·2	58·3	59·4	60·5
60	53·4	54·5	55·6	56·7	57·8	58·9	61·1	62·2	63·3	64·4	65·5
65	58·4	59·5	60·6	61·7	62·8	63·9	66·0	67·1	68·2	69·3	70·4
70	63·5	64·6	65·7	66·8	67·9	69·0	71·0	72·1	73·2	74·3	75·4
75	68·6	69·7	70·7	71·8	72·9	74·0	76·0	77·1	78·2	79·2	80·3
80	73·7	74·8	75·8	76·9	78·0	79·0	81·0	82·1	83·1	84·1	85·2
85	78·8	79·8	80·9	81·9	83·0	84·0	86·0	87·0	88·0	89·0	90·0
90	84·0	85·1	86·1	87·1	88·1	89.1	91·0	91·9	92·8	93·7	94·6

Thus, if the alcoholometer indicated 59·4 per cent. in a liquid at 80°, the table would give its true per centage—richness—to 55 per cent., that is, 100 volumes of the liquid, at 80°, contain 55 volumes of anhydrous alcohol.

TABLE X.

To find the true per centage of absolute alcohol in a liquid of any temperature, from the observed per centage indicated by a brass alcoholometer at the same temperature.

True per cent. of alcohol by volume.	Observed per cent. indicated by the brass alcoholometer.										
	30°	35°	40°	45°	50°	55°	65°	70°	75°	80°	85°
0	— 0·1	— 0·1	— 0·2	— 0·3	— 0·3	— 0·2	+ 0·2	+ 0·5	+ 0·9	+ 1·2	+ 1·7
5	+ 5·0	+ 4·8	+ 4·7	+ 4·8	+ 4·7	+ 4·8	5·2	5·6	6·1	6·5	7·0
10	9·5	9·4	9·4	9·4	9·5	9·7	10·3	10·8	11·4	12·0	12·6
15	13·5	13·5	13·6	13·7	14·0	14·6	15·5	16·2	17·0	17·7	18·6
20	17·0	17·3	17·7	18·1	18·7	19·3	20·7	21·6	22·7	23·7	24·0
25	20·3	20·9	21·6	22·4	23·3	24·2	25·8	26·9	28·1	29·2	30·3
30	23·8	24·7	25·8	26·8	27·8	28·9	31·1	32·2	33·3	34·4	35·5
35	28·2	29·3	30·4	31·6	32·8	33·9	36·2	37·3	38·4	39·5	40·7
40	32·9	34·1	35·4	36·7	37·9	39·0	41·1	42·2	43·4	44·5	45·6
45	38·1	39·3	40·4	41·6	42·7	43·9	46·1	47·2	48·3	49·4	50·5
50	43·4	44·5	45·6	46·7	47·8	48·9	51·1	52·2	53·3	54·4	55·5
55	48·5	49·6	50·7	51·8	52·9	54·0	56·0	57·1	58·2	59·3	60·4
60	53·6	54·6	55·7	56·8	57·8	58·9	61·0	62·1	63·2	64·3	65·3
65	58·6	59·7	60·7	61·8	62·8	63·9	66·0	67·1	68·1	69·2	70·2
70	63·7	64·8	65·8	66·9	67·9	69·0	71·0	72·1	73·1	74·2	75·2
75	68·8	69·8	70·9	71·9	72·9	74·0	76·0	77·0	78·1	79·1	80·1
80	73·9	74·9	75·9	76·9	78·0	79·0	81·0	82·0	83·0	84·0	85·0
85	79·0	80·0	81·0	82·0	83·0	84·0	86·0	87·0	88·0	88·9	89·9
90	84·2	85·2	86·2	87·2	88·1	89.1	90·9	91·9	92·8	93·7	94·5

The preceding ten tables of Tralles contain all that is requisite for the determination of the volume of alcohol in a liquid; they have been constructed on the principle of the tables of Gilpin. Since their construction, however, further extensive researches have been instituted by various eminent chemists, among whom was the famous Gay-Lussac, whose investigations had been made in 1824. The tables drawn up by that chemist are much more extensive, requiring scarcely any interpolation.

Gay-Lussac's instrument, called an *alcoomètre*, is like a glass hydrometer, the stem of which is divided into degrees like that of Tralles, to indicate the per centage of alcohol by volume, but the temperature at which the gradation was made was 15° C. or 59° Fahr., instead of 60° Fahr., as the normal temperature of Tralles' tables.

At this temperature, water is supposed to be at its maximum density or unity, although this actually happens when the temperature is reduced to 39·83° Fahr. The stem of the instrument is divided, from the point at which it stands in water, into one hundred divisions, so that each on the scale is equal to a per cent. of alcohol; the hundredth division indicates pure or absolute alcohol, while 0 or zero equals pure water.

The instrument, if immersed in an alcoholic liquor at 59°, marks the strength by the number of degrees below the surface; thus, if the alcoholometer stands at 57 in a liquid at 59°, such a solution contains 57 per cent. by volume of alcohol.

In consequence of the assumed density of water, taken by Gay-Lussac at 59°, the fundamental numbers for determining the relation, the per centage of alcohol and the specific gravities, are in a slight degree different from those of Tralles, but the variation is so minute that in practice it may be overlooked.

In the annexed table the fundamental numbers of the centesimal content per volume, together with the specific gravities of the different alcoholic mixtures at 59°, are given:

Per cent. of alcohol by volume.	Specific gravity of the liquid at 59°.	Per cent. of alcohol by volume.	Specific gravity of the liquid at 59°.
100	0·7947	60	0·9141
95	0·8168	55	0·9248
90	0·8346	50	0·9348
85	0·8502	45	0·9440
80	0·8645	40	0·9523
75	0·8799	35	0·9595
70	0·8907	10	0·9656
65	0·9027	0	1·0000

The first table by Gay-Lussac is denominated *Table for the* REAL *strength of spirits*, and corresponds with Table VIII. of Tralles. This table gives the true per centage by volume at 59° from the observed per centage of the alcoholometer at any other temperature. Two numbers are placed in the same horizontal column, and vertical to each other: those in the top are the observed centesimal quantities of the alcoholometer, while the large figures in the vertical column below them, give the real per centages at 59°, when tested at the temperature found in the left-hand vertical column. The numbers in small figures beneath the real per centages denote the bulk at 59° of a thousand measures of liquid; this number, multiplied by the real per centage under which it stands, gives the richness, or absolute quantity of alcohol at the temperature at which the experiment is performed. To read the table, suppose an alcoholic liquid of 50 strength indicated by the alcoholometer at a temperature of 68° Fahr., the observed per centage—50—is sought in the horizontal column at the top; in the vertical column beneath this and on a line with 68°, in the temperature column at the left hand, will be found the number 48·2, which is the quantity of *real* spirit at 59°. The number 996, in small figures below the indicated strength at 59°, is the bulk or volume which a thousand volumes would occupy at the standard temperature; and by multiplying this number by the proper strength, and dividing the product by a thousand, the strength or true volume of spirit in a thousand of the liquid is ascertained; thus—

996 × 48·2 = 48007·2 ÷ 1000 = 48·00, the per centage;

hence, a hundred volumes of the liquor at 68°, contain 48 volumes of absolute alcohol at 59°.

M. Morazeau constructed a table somewhat more in detail than the foregoing, with one of Gay-Lussac's alcoholometers, which differs slightly from the preceding in the figures denoting the density, although they have reference to the same temperature.

When, however, the liquors to be tested stand at a higher degree than 59°, no provision is made to afford the true content of spirit, which must be sought, in this case, either by other tables, or by the tedious calculation exemplified on a former occasion.

Per cent. of alcohol by volume.	Specific gravity.	Per cent. of alcohol by volume.	Specific gravity.	Per cent. of alcohol by volume.	Specific gravity.
0	1·000	34	0·962	68	0·896
1	0·999	35	0·960	69	0·893
2	0·997	36	0·959	70	0·891
3	0·996	37	0·957	71	0·888
4	0·994	38	0·956	72	0·884
5	0·993	39	0·954	73	0·881
6	0·992	40	0·953	74	0·879
7	0·990	41	0·951	75	0·876
8	0·989	42	0·949	76	0·874
9	0·988	43	0·948	77	0·871
10	0·987	44	0·946	78	0·868
11	0·986	45	0·945	79	0·865
12	0·984	46	0·943	80	0·863
13	0·983	47	0·941	81	0·860
14	0·982	48	0·940	82	0·857
15	0·981	49	0·938	83	0·854
16	0·980	50	0·936	84	0·851
17	0·979	51	0·934	85	0·848
18	0·978	52	0·932	86	0·845
19	0·977	53	0·930	87	0·842
20	0·976	54	0·928	88	0·838
21	0·975	55	0·926	89	0·835
22	0·974	56	0·924	90	0·832
23	0·973	57	0·922	91	0·829
24	0·972	58	0·920	92	0·826
25	0·971	59	0·918	93	0·822
26	0·970	60	0·915	94	0·818
27	0·969	61	0·913	95	0·814
28	0·968	62	0·911	96	0·810
29	0·967	63	0·909	97	0·805
30	0·966	64	0·906	98	0·800
31	0·965	65	0·904	99	0·795
32	0·964	66	0·902	100	0·747
33	0·963	67	0·899		

TABLE I.

ALCOHOLOMETRIC TABLE BY GAY-LUSSAC,

To find the per cent., by volume, in a liquid at 59°—strength—from the observed per cent. at any other Temperature.
The temperature by Centigrade is below that of Fahrenheit.

Temp. Fahr.	Observed per centage of the Alcoholometer.										Observed per centage of the Alcoholometer.									
	1 p.cent.	2 p.cent.	3 p.cent.	4 p.cent.	5 p.cent.	6 p.cent.	7 p.cent.	8 p.cent.	9 p.cent.	10 p.cent.	11 p.cent.	12 p.cent.	13 p.cent.	14 p.cent.	15 p.cent.	16 p.cent.	17 p.cent.	18 p.cent.	19 p.cent.	20 p.cent.
32·0° 0° C.	1·3 1000	2·4 1000	3·4 1000	4·4 1000	5·4 1000	6·5 1001	7·5 1001	8·6 1001	9·7 1001	10·9 1001	12·2 1001	13·4 1002	14·7 1002	16·1 1002	17·5 1002	18·9 1003	20·3 1003	21·6 1004	22·9 1004	24·2 1004
33·8 1 C.												13·4 1002	14·7 1002	16 1002	17·3 1002	18·7 1003	20 1003	21·3 1003	22·6 1004	23·9 1004
35·6 2 C.												13·4 1002	14·7 1002	16 1002	17·2 1002	18·5 1003	19·8 1003	21·1 1003	22·3 1004	23·6 1004
37·4 3 C.												13·3 1001	14·6 1002	15·9 1002	17·1 1002	18·3 1002	19·6 1003	20·8 1003	22 1003	23·3 1004
39·2 4 C.												13·3 1001	14·5 1002	15·8 1002	16·9 1002	18·1 1002	19·4 1002	20·6 1003	21·8 1003	23 1003
41·0 5 C.	1·4 1001	2·5 1001	3·5 1001	4·5 1001	5·5 1001	6·6 1001	7·7 1001	8·7 1001	9·8 1001	10·9 1001	12·1 1001	13·2 1001	14·4 1001	15·7 1002	16·8 1002	18 1002	19·2 1002	20·4 1003	21·5 1003	22·7 1003
42·8 6 C.												13·1 1001	14·3 1001	15·6 1002	16·7 1002	17·8 1002	19 1002	20·2 1003	21·3 1003	22·4 1003
44·6 7 C.												13 1001	14·2 1001	15·4 1001	16·6 1002	17·7 1002	18·8 1002	20 1002	21 1002	22·1 1002
46·4 8 C.												13 1001	14·1 1001	15·3 1001	16·4 1001	17·5 1001	18·6 1002	19·7 1002	20·7 1002	21·8 1002
48·2 9 C.												12·9 1001	14 1001	15·1 1001	16·2 1001	17·3 1001	18·4 1001	19·5 1001	20 5 1002	21·6 1002
50·0 10 C.	1·4 1000	2·4 1000	3·4 1001	4·5 1001	5·5 1001	6·5 1001	7·5 1001	8·5 1001	9·5 1001	10·6 1001	11·7 1001	12·7 1001	13·8 1001	14·9 1001	16 1001	17 1001	18·1 1001	19·2 1001	20·2 1001	21·3 1001
51·8 11 C.	1·3 1000	2·4 1000	3·4 1000	4·4 1001	5·4 1001	6·4 1001	7·4 1001	8·4 1001	9·4 1001	10·5 1001	11·6 1001	12·6 1001	13·6 1001	14·7 1001	15·8 1001	16·8 1001	17·9 1001	19 1001	20 1001	21 1001
53·6 12 C.	1·2 1000	2·3 1000	3·3 1000	4·3 1000	5·3 1000	6·3 1000	7·3 1000	8·3 1000	9·3 1000	10·4 1000	11·5 1000	12·5 1001	13·5 1001	14·6 1001	15·6 1001	16·6 1001	17·6 1001	18·7 1001	19·7 1001	20·7 1001
55·4 13 C.	1·2 1000	2·2 1000	3·2 1000	4·2 1000	5·2 1000	6·2 1000	7·2 1000	8·2 1000	9·2 1000	10·3 1000	11·4 1000	12·4 1000	13·4 1000	14·4 1000	15·4 1000	16·4 1000	17·4 1000	18·5 1000	19·5 1000	20·5 1000
57·2 14 C.	1·1 1000	2·1 1000	3·1 1000	4.1 1000	5·1 1000	6·1 1000	7·1 1000	8·1 1000	9·1 1000	10·2 1000	11·2 1000	12·2 1000	13·2 1000	14·2 1000	15·2 1000	16·2 1000	17·2 1000	18·2 1000	19·2 1000	20·2 1000
59·0 15 C.	1 1000	2 1000	3 1000	4 1000	5 1000	6 1000	7 1000	8 1000	9 1000	10 1000	11 1000	12 1000	13 1000	14 1000	15 1000	16 1000	17 1000	18 1000	19 1000	20 1000
60·8 16 C.	0·9 1000	1·9 1000	2·9 1000	3·9 1000	4·9 1000	5·9 1000	6·9 1000	7·9 1000	8·9 1000	9·9 1000	10·9 1000	11·9 1000	12·9 1000	13·9 1000	14·9 1000	15·9 1000	16·9 1000	17·8 1000	18·7 1000	19·7 1000
62·6 17 C.	0·8 1000	1·8 1000	2·8 1000	3·8 1000	4·8 1000	5·8 1000	6·8 1000	7·8 1000	8·8 1000	9·8 1000	10·8 1000	11·7 1000	12·7 1000	13·7 1000	14·7 1000	15·6 1000	16·6 1000	17·5 1000	18·4 999	19·4 999
64·4 18 C.	0·7 1000	1·7 1000	2·7 1000	3·7 1000	4·7 1000	5·7 1000	6·7 1000	7·7 1000	8·7 1000	9·7 1000	10·7 1000	11·6 1000	12·5 999	13·5 999	14·5 999	15·4 999	16·3 999	17·3 999	18·2 999	19·1 999
66·2 19 C.	0·6 999	1·6 999	2·6 999	3·6 999	4·5 999	5·5 999	6·5 999	7·5 999	8·5 999	9·5 999	10·5 999	11·4 999	12·4 999	13·3 999	14·3 999	15·2 999	16·1 999	17 999	17·9 999	18·8 999
68·0 20 C.	0·5 999	1·5 999	2·4 999	3·4 999	4·4 999	5·4 999	6·4 699	7·3 999	8·3 999	9·3 999	10·3 999	11·2 999	12·2 999	13·1 999	14 999	14·9 999	15·8 999	16·7 999	17·6 999	18·5 999
69·8 21 C.	0·4 999	1·4 999	2·3 999	3·3 999	4·3 999	5·2 999	6·2 999	7·1 999	8·1 999	9·1 999	10·1 999	11 999	11·9 999	12·8 999	13·7 999	14·6 999	15·5 998	16·4 998	17·3 998	18·2 998
71·6 22 C.	0·3 999	1·3 999	2·2 999	3·2 999	4·1 999	5·1 999	6·1 999	7 999	7·9 999	8·9 999	9·9 999	10·8 999	11·7 999	12·6 998	13·5 998	14·4 998	15·3 998	16·2 998	17 998	17·9 998
73·4 23 C.	0·1 999	1·1 999	2·1 999	3·1 999	4 999	4·9 599	5·9 999	6·8 998	7·8 998	8·7 998	9·7 998	10·6 998	11·5 998	12·4 998	13·3 998	14·1 998	15 998	15·9 998	16·7 998	17·6 998
75·2 24 C.		1 998	1·9 998	2·9 998	3·8 998	4·8 998	5·8 998	6·7 998	7·6 998	8·5 998	9·5 998	10·4 998	11·3 998	12·2 998	13·1 998	13·9 998	14·8 998	15·7 998	16·5 997	17·4 997
77·0 25 C.		0·8 998	1·7 998	2·7 998	3·6 998	4·6 998	5·5 998	6·5 998	7·4 998	8·3 998	9·3 998	10·2 998	11·1 998	12 998	12·8 998	13·6 998	14·5 997	15·4 997	16·2 997	17·1 997
78·8 26 C.		0·7 998	1·6 998	2·6 998	3·5 998	4·4 998	5·4 998	6·3 998	7·2 998	8·1 998	9 998	9·9 997	10·8 997	11·7 997	12·6 997	13·4 997	14·2 997	15·1 997	15·9 997	16·8 997
80·6 27 C.		0·5 998	1·5 998	2·4 998	3·3 998	4·3 998	5·2 998	6·1 998	7 998	7·9 998	8·8 997	9·7 997	10·6 997	11·5 997	12·3 997	13·1 997	14 997	14·8 997	15·6 997	16·5 997
82·4 28 C.		0·3 997	1·3 997	2·2 997	3·1 997	4·1 997	5 997	5·9 497	6·8 997	7·7 997	8·6 997	9·5 997	10·3 997	11·2 997	12 967	12·8 996	13·7 996	14·5 996	15·3 996	16·1 996
84·2 29 C.		0·1 997	1·1 997	2 997	2·9 997	3·9 997	4·8 997	5·7 997	6·6 997	7·5 697	8·4 997	9·2 997	10·1 997	11 997	11·8 996	12·6 996	13·4 996	14·2 996	15 996	15·8 996
86·0 30 C.		0·0 997	0·9 997	1·9 997	2·8 997	3·7 997	4·6 997	5·5 997	6·4 997	7·3 997	8·1 997	9 996	9·8 996	10·7 996	11·5 996	12·3 996	13·1 996	13·9 996	14·7 996	15·5 996

TABLE I.—Continued.

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	21 p.cent.	22 p.cent.	23 p.cent.	24 p.cent.	25 p.cent.	26 p.cent.	27 p.cent.	28 p.cent.	29 p.cent.	30 p.cent.
32·0° 0° C.	25.6 1005	27 1005	28·4 1006	29·7 1006	30·9 1007	32·1 1007	33·2 1007	34·3 1008	35·3 1008	36·3 1008
33·8 1 C.	25·3 1005	26·7 1005	28 1005	29·2 1006	30·4 1006	31·6 1006	32·7 1007	33·8 1007	34·8 1007	35·8 1008
35·6 2 C.	24·9 1004	26·3 1005	27·5 1005	28·8 1005	30 1006	31·2 1006	32·3 1006	33·3 1006	34·4 1007	35·4 1007
37·4 3 C.	24·6 1004	25·9 1005	27·1 1005	28·4 1005	29·6 1005	30·8 1006	31·9 1006	32·9 1006	33·9 1007	34·9 1007
39·2 4 C.	24·3 1004	25·6 1004	26·8 1005	28 1005	29·2 1005	30·4 1005	31·4 1005	32·5 1005	33·5 1006	34·5 1006
41·0 5 C.	24 1003	25·2 1003	26·4 1004	27·6 1004	28·8 1004	30 1004	31 1005	32·1 1005	33·1 1005	34·1 1005
42·8 6 C.	23·6 1003	24·9 1003	26 1004	27·2 1004	28·4 1004	29·6 1004	30·6 1005	31·6 1005	32·6 1005	33·6 1005
44·6 7 C.	23·3 1002	24·6 1003	25·7 1003	26·9 1003	28 1003	29·2 1003	30·2 1004	31.2 1004	32·2 1004	33·2 1004
46·4 8 C.	23 1002	24·2 1002	25·3 1003	26·5 1003	27·6 1003	28·8 1003	29·8 1003	30·8 1003	31·8 1003	32·8 1003
48·2 9 C.	22·7 1002	23·9 1002	25 1002	26·1 1002	27·2 1002	28·4 1003	29·4 1003	30·4 1003	31·4 1003	32·4 1003
50·0 10 C.	22·4 1001	23·5 1002	24·6 1002	25·7 1002	26·8 1002	27·9 1002	29 1002	30 1002	31 1002	32 1002
51·8 11 C.	22·1 1001	23·2 1001	24·3 1001	25·4 1001	26·5 1002	27·6 1002	28·6 1002	29·6 1002	30·6 1002	31·6 1002
53·6 12 C.	21·8 1001	22·9 1001	24 1001	25·1 1001	26·1 1001	27·2 1001	28·2 1001	29·2 1001	30·2 1001	31·2 1001
55·4 13 C.	21·5 1001	22·6 1001	23·6 1001	24·7 1001	25·7 1001	26·8 1001	27·8 1001	28·8 1001	29·8 1001	30·8 1001
57·2 14 C.	21·2 1000	22·3 1000	23·3 1000	24·3 1000	25·3 1000	26·4 1000	27·4 1000	28·4 1000	29·4 1000	30·4 1000
59·0 15 C.	21 1001	22 1000	23 1000	24 1000	25 1000	26 1000	27 1000	28 1000	29 1000	30 1000
60·8 16 C.	20·7 1000	21·7 1000	22·7 1000	23·7 1000	24·7 1000	25·7 1000	26·6 1000	27·6 1000	28·6 1000	29·6 1000
62·6 17 C.	20·4 999	21·4 999	22·4 999	23·4 999	24·4 999	25·4 999	26·3 999	27·3 999	28·2 999	29·2 999
64·4 18 C.	20·1 999	21·1 999	22 999	23 999	24 999	25 999	25·9 999	26·9 999	27·8 999	28·8 999
66·2 19 C.	19·8 999	20·8 999	21·7 999	22·7 999	23·6 998	24·6 998	25·5 998	26·5 998	27·4 998	28·4 998
68·0 20 C.	19·5 999	20·5 998	21·4 998	22·4 998	23·3 998	24·3 998	25·2 998	26·1 998	27·1 998	28 998
69·8 21 C.	19·1 998	20·1 998	21.1 998	22·1 998	23 998	23·9 998	24·8 998	25·7 998	26·7 997	27·6 997
71·6 22 C.	18·8 998	19·8 998	20·7 998	21·7 997	22·6 997	23·6 997	24·4 997	25·3 997	26·3 997	27·2 997
73·4 23 C.	18·5 998	19·5 997	20·4 997	21·4 997	22·3 997	23·2 997	24·1 997	25 997	25·9 997	26·8 997
75·2 24 C.	18·3 997	19·2 997	20·1 997	21·1 997	21·9 997	22·8 997	23·7 997	24·6 996	25·5 996	26·4 996
77·0 25 C.	18 997	18·9 997	19·8 997	20·7 997	21·6 996	22·5 996	23·3 996	24·3 996	25·2 996	26·1 996
78·8 26 C.	17·7 997	18·6 996	19·5 996	20·4 996	21·3 996	22·2 996	23 996	23·9 996	24·8 995	25·7 995
80·6 27 C.	17·4 996	18·3 996	19·2 996	20·1 996	20·9 996	21·8 996	22·7 996	23·6 996	24·4 995	25·3 995
82·4 28 C.	17 996	18 996	18·9 996	19·7 995	20·6 995	21·5 995	22·3 995	23·2 995	24 995	24·9 994
84·2 29 C.	16·7 996	17·6 996	18·5 995	19·4 995	20·3 995	21·1 995	21·9 995	22·8 994	23·7 994	24·5 994
86·0 30 C.	16·4 995	17·3 995	18·2 995	19·1 995	19·9 995	20·8 994	21·6 994	22·5 994	23·3 994	24·2 994

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	31 p.cent.	32 p.cent.	33 p.cent.	34 p.cent.	35 p.cent.	36 p.cent.	37 p.cent.	38 p.cent.	39 p.cent.	40 p.cent.
32·0° 0° C.	37·3 1009	38·3 1009	39·2 1009	40·2 1009	41·1 1009	42·1 1010	43·1 1010	44 1010	45 1010	45·9 1011
33·8 1 C.	36·8 1008	37·8 1008	38·8 1008	39·8 1008	40·8 1009	41·8 1009	42·7 1009	43·7 1009	44·6 1010	45 5 1010
35·6 2 C.	36·4 1007	37·4 1007	38·4 1008	39·4 1008	40·4 1008	41·4 1008	42·3 1008	43·3 1009	44·2 1009	45·1 1009
37·4 3 C.	36 1007	37 1007	38 1007	39 1007	40 1007	41 1008	42 1008	42·9 1008	43·9 1008	44·8 1008
39·2 4 C.	35·5 1006	36·5 1006	37·5 1006	38·5 1007	39·5 1007	40·5 1007	41·5 1007	42·5 1007	43·5 1007	44·4 1008
41·0 5 C.	35·1 1005	36·1 1006	37·1 1006	38·1 1006	39·1 1006	40·1 1006	41·1 1007	42·1 1007	43·1 1007	44 1007
42·8 6 C.	34·7 1005	35·7 1005	36·7 1005	37·7 1005	38·7 1005	39·7 1006	40·7 1006	41 1006	42·6 1006	43·6 1006
44·6 7 C.	34·2 1004	35·2 1004	36·2 1004	37·2 1005	38·2 1005	39·2 1005	40·2 1005	41·2 1005	42·2 1005	43·2 1005
46·4 8 C.	33·8 1004	34·8 1004	35·8 1004	36·8 1004	37·8 1004	38·8 1004	39·8 1004	40·8 1004	41·8 1004	42·8 1005
48·2 9 C.	33·4 1003	34·4 1003	35·4 1003	36·4 1003	37·4 1004	38·4 1004	39·4 1004	40 4 1004	41·4 1004	42·4 1004
50·0 10 C.	33 1002	34 1002	35 1003	36 1003	37 1003	38 1003	39 1003	40 1003	41 1003	42 1003
51·8 11 C.	32·6 1002	33·6 1002	34·6 1002	35·6 1002	36·6 1002	37·6 1002	38·6 1002	39·6 1002	40·6 1003	41·6 1003
53·6 12 C.	32·2 1001	33·2 1001	34·2 1002	35·2 1002	36·2 1002	37·2 1002	38·2 1002	39·2 1002	40·2 1002	41·2 1002
55·4 13 C.	31·8 1001	32·8 1001	33·8 1001	34·8 1001	35·8 1001	36·8 1001	37·8 1001	38·8 1001	39·8 1001	40·8 1001
57·2 14 C.	31·4 1000	32·4 1000	33·4 1001	34·4 1001	35·4 1001	36·4 1001	37·4 1001	38·4 1001	39·4 1001	40·4 1001
59·0 15 C.	31 1000	32 1000	33 1000	34 1000	35 1000	36 1000	37 1000	38 1000	39 1000	40 1000
60·8 16 C.	30·6 1000	31·6 1000	32.5 999	33·5 999	34·5 999	35·5 999	36·5 999	37·5 999	38·5 999	39·5 999
62·6 17 C.	30·2 999	31·2 999	32·1 999	33·1 999	34·1 999	35·1 999	36·1 999	37 1 999	38·1 999	39·1 999
64·4 18 C.	29·8 999	30·8 999	31·7 998	32·7 998	33·7 998	34·7 998	35 7 998	36·7 998	37·7 998	38·7 998
66·2 19 C.	29·4 998	30·4 998	31·3 993	32·3 998	33·3 998	34·3 998	35·3 998	36·3 998	37·3 997	38·3 997
68·0 20 C.	29 998	30 998	30·9 997	31·9 997	32·9 997	33·9 997	34·9 997	35·9 997	36·9 997	37·9 997
69·8 21 C.	28·6 997	29·6 997	30·5 997	31·5 997	32·5 997	33·5 997	34·5 997	35·5 996	36·5 996	37·5 996
71·6 22 C.	28·2 997	29·2 997	30·1 996	31·1 996	32·1 996	33·1 996	34·1 996	35·1 996	36·1 996	37·1 996
73·4 23 C.	27·8 996	28·8 996	29·7 996	30·7 996	31·7 996	32·7 996	33·7 996	34·7 995	35·7 995	36·7 995
75·2 24 C.	27·4 996	28·4 996	29·3 995	30·3 995	31·3 995	32·3 995	33·3 995	34·3 995	35·3 995	36·3 994
77·0 25 C.	27 995	28 995	28·9 995	29·9 995	30·9 995	31·9 994	32·9 994	33·9 994	34·9 994	35·9 994
78·8 26 C.	26·6 995	27·6 995	28·5 995	29·5 994	30·5 994	31·5 994	32·5 994	33·5 994	34·5 993	35·5 993
80·6 27 C.	26·2 995	27·2 994	28·1 994	29·1 994	30·1 994	31·1 993	32·1 993	33·1 993	34·1 993	35·1 993
82·4 28 C	25·8 994	26·8 994	27·7 994	28·7 993	29·7 993	30·7 993	31·7 993	32·7 993	33·7 992	34·7 992
84·2 29 C.	25·4 994	26·4 993	27·3 993	28·3 993	29·3 993	30·3 992	31·3 992	32·3 992	33·3 992	34·3 992
86·0 30 C.	25·1 993	26 993	26·9 993	27·9 993	28·9 992	29·9 992	30·9 992	31·9 991	32·9 991	33·9 991

Table I.—Continued.

Temp. Fahr.	Observed per centage of the Alcoholometer.										Temp. Fahr.	Observed per centage of the Alcoholometer.									
	41 p.cent.	42 p.cent.	43 p.cent.	44 p.cent.	45 p.cent.	46 p.cent.	47 p.cent.	48 p.cent.	49 p.cent.	50 p.cent.		51 p.cent.	52 p.cent.	53 p.cent.	54 p.cent.	55 p.cent.	56 p.cent.	57 p.cent.	58 p.cent.	59 p.cent.	60 p.cent.
32·0° 0° C.	46·9 1011	47·9 1011	48·8 1011	49·8 1011	50·7 1011	51·7 1011	52·6 1012	53·5 1012	54·5 1012	55·4 1012	32·0° 0° C.	56·4 1012	57·3 1012	58·3 1012	59·2 1012	60·2 1012	61·2 1012	62·1 1012	63.1 1013	64·1 1013	65 1013
33·8 1 C.	46·5 1010	47·5 1010	48.4 1010	49·4 1010	50·3 1010	51·3 1011	52·2 1011	53·2 1011	54·2 1011	55·1 1011	33·8 1 C.	56 1011	57 1011	57·9 1011	58·9 1011	59·9 1011	60·9 1011	61·8 1011	62·8 1012	63·8 1012	64·7 1012
35·6 2 C.	46·1 1009	47·1 1009	48·1 1009	49 1009	49·9 1010	50·9 1010	51·8 1010	52·8 1010	53·8 1010	54·7 1010	35·6 2 C.	55·7 1010	56·6 1010	57·6 1010	58·5 1010	59·5 1010	60·5 1011	61·5 1011	62 4 1011	63·4 1011	64·4 1011
37·4 3 C.	45·8 1008	46·7 1009	47·7 1009	48·6 1009	49·6 1009	50·5 1009	51·5 1009	52·4 1009	53·4 1009	54·3 1009	37·4 3 C.	55·3 1009	56·3 1009	57·2 1009	58·2 1010	59·2 1010	60·2 1010	61·1 1010	62·1 1010	63·1 1010	64·1 1010
39·2 4 C.	45·4 1008	46·4 1008	47·4 1008	48·3 1008	49·2 1008	50·2 1008	51·1 1008	52·1 1008	53 1008	54 1009	39·2 4 C.	55 1009	56 1009	56·9 1009	57·9 1009	58·9 1009	59·8 1009	60·8 1009	61·7 1009	62·7 1009	63·7 1009
41·0 5 C.	45 1007	45·9 1007	46·9 1007	47·9 1007	48·8 1007	49·8 1007	50·7 1007	51·7 1008	52·7 1008	53·6 1008	41·0 5 C.	54·6 1008	55·6 1008	56·6 1008	57·5 1008	58·5 1008	59·5 1008	60·4 1008	61·4 1008	62·4 1008	63·4 1008
42·8 6 C.	44·6 1006	45·5 1006	46·5 1006	47·5 1007	48·4 1007	49·4 1007	50·4 1007	51·4 1007	52·4 1007	53·3 1007	42·8 6 C.	54·3 1007	55·2 1007	56·2 1007	57·1 1007	58·1 1007	59·1 1007	60·1 1007	61 1008	62 1008	63 1008
44·6 7 C.	44·2 1005	45·1 1006	46·1 1006	47·1 1006	48·1 1006	49·1 1006	50·1 1006	51 1006	52 1006	52·9 1006	44·6 7 C.	53·9 1006	54·9 1006	55·9 1006	56·8 1006	57·8 1006	58·8 1006	59·8 1007	60·7 1007	61·7 1007	62·7 1007
46·4 8 C.	43·8 1005	44·8 1005	45·8 1005	46·8 1005	47·7 1005	48·7 1005	49·7 1005	50·6 1005	51·6 1005	52·6 1005	46·4 8 C.	53·6 1005	54·6 1005	55·5 1006	56·5 1006	57·5 1006	58·5 1006	59·5 1006	60·4 1006	61·4 1006	62·4 1006
48·2 9 C.	43·4 1004	44·4 1004	45·4 1004	46·4 1004	47·3 1004	48·3 1004	49·3 1005	50·2 1005	51·2 1005	52·2 1005	48·2 9 C.	53·2 1005	54·2 1005	55·1 1005	56·1 1005	57·1 1005	58·1 1005	59·1 1005	60 1005	61 1005	62 1005
50·0 10 C.	43 1003	44 1004	45 1004	46 1004	46·9 1004	47·9 1004	48·9 1004	49·9 1004	50·9 1004	51·8 1004	50·0 10 C.	52·8 1004	53·8 1004	54·8 1004	55·8 1004	56·8 1004	57·8 1004	58·8 1004	59·7 1004	60·7 1004	61·7 1004
51·8 11 C.	42·6 1003	43·6 1003	44·6 1003	45·6 1003	46·6 1003	47·6 1003	48·6 1003	49·5 1003	50·5 1003	51·5 1003	51·8 11 C.	52·5 1003	53·5 1003	54·4 1003	55·4 1003	56·4 1003	57·4 1003	58·4 1003	59·4 1003	60·4 1003	61·4 1003
53·6 12 C.	42·2 1002	43·2 1002	44·2 1002	45·2 1002	46·2 1002	47·2 1002	48·2 1002	49·2 1002	50·2 1002	51·1 1002	53·6 12 C.	52·1 1002	53·1 1002	54·1 1002	55 1002	56 1002	57 1002	58 1002	59 1002	60 1002	61 1002
55·4 13 C.	41·8 1001	42·8 1001	43·8 1001	44·8 1002	45·8 1002	46·8 1002	47·8 1002	48·8 1002	49·8 1002	50·8 1002	55·4 13 C.	51·8 1002	52·7 1002	53·7 1002	54·7 1002	55·7 1002	56·7 1002	57·7 1002	58·7 1002	59·7 1002	60·7 1002
57·2 14 C.	41·4 1001	42·4 1001	43·4 1001	44·4 1001	45·4 1001	46·4 1001	47·4 1001	48·4 1001	49·4 1001	50·4 1001	57·2 14 C.	51·4 1001	52·3 1001	53·3 1001	54·3 1001	55·3 1001	56·3 1001	57·3 1001	58·3 1001	59·3 1001	60·3 1001
59·0 15 C.	41 1000	42 1000	43 1000	44 1000	45 1000	46 1000	47 1000	48 1000	49 1000	50 1000	59·0 15 C.	51 1000	52 1000	53 1000	54 1000	55 1000	56 1000	57 1000	58 1000	59 1000	60 1000
60·8 16 C.	40·6 999	41·6 999	42·6 999	43·6 999	44·6 999	45·6 999	46·6 999	47·6 999	48·6 999	49·6 999	60·8 16 C.	50·6 999	51·6 999	52.6 999	53·6 999	54·6 999	55·6 999	56·6 999	57·6 999	58·6 999	59·6 999
62·6 17 C.	40·2 999	41·2 999	42·2 999	43·2 998	44·2 998	45·2 998	46·2 998	47·2 998	48·3 998	49·3 998	62·6 17 C.	50·3 998	51·3 998	52·3 998	53·3 998	54·3 998	55·3 998	56·3 998	57·3 998	58·3 998	59·3 998
64·4 18 C.	39·8 998	40·8 998	41·8 998	42·8 998	43·8 998	44·9 998	45·9 998	46·9 998	47·9 998	48·9 998	64·4 18 C.	49·9 998	50·9 998	51·9 998	52·9 998	53·9 998	54·9 998	55·9 998	56·9 997	57·9 997	58·9 997
66·2 19 C.	39·4 997	40·4 997	41·4 997	42·5 997	43·5 997	44·5 997	45·5 997	46·5 997	47·5 997	48·5 997	66·2 19 C.	49·5 997	50·6 997	51·6 997	52·6 997	53·6 997	54·6 997	55·6 997	56·6 997	57·6 997	58·6 997
68·0 20 C.	39 997	40 997	41 997	42·1 997	43·1 996	44·1 996	45·1 996	46·1 996	47·2 996	48·2 996	68·0 20 C.	49·2 996	50·2 996	51·2 996	52·2 996	53·2 996	54·2 996	55·2 996	56·2 996	57·2 996	58·2 996
69·8 21 C.	38·6 996	39·6 996	40.6 996	41·7 996	42·7 996	43·7 996	44·8 996	45·8 996	46·8 995	47·8 995	69·8 21 C.	48·8 995	49·8 995	50·8 995	51·8 995	52·9 995	53·9 995	54·9 995	55·9 995	56·9 995	57·9 995
71·6 22 C.	38·2 996	39·2 995	40·2 995	41·3 995	42·3 995	43·3 995	44·3 995	45·3 995	46·4 995	47·4 995	71·6 22 C.	48·4 995	49·4 995	50·4 995	51·4 994	52·5 994	53·5 994	54·5 994	55·5 994	56·5 994	57·5 994
73·4 23 C.	37·8 995	38·8 995	39·8 995	40·9 994	41·9 994	42·9 994	43·9 994	44·9 994	46 994	47 994	73·4 23 C.	48 994	49·1 994	50 1 994	51·1 994	52·1 994	53·1 994	54·1 993	55·1 993	56·1 993	57·1 993
75·2 24 C.	37·4 994	38·4 994	39·4 994	40·5 994	41·5 994	42·5 994	43·6 994	44·6 994	45·6 993	46·6 993	75·2 24 C.	47·6 993	48·7 993	49·7 993	50·7 993	51·8 993	52·8 993	53·8 993	54·8 993	55·8 993	56·8 992
77·0 25 C.	37 994	38 994	39 993	40·1 993	41·1 993	42·2 993	43·2 993	44·2 993	45·2 993	46·3 993	77·0 25 C.	47·3 993	48·3 993	49·3 993	50·3 992	51·4 992	52·4 992	53·4 992	54·4 992	55·5 992	56·5 992
78·8 26 C.	36·5 993	37·6 993	38·6 993	39·7 993	40·7 992	41·8 992	42·8 992	43·8 992	44·9 992	45·9 992	78·8 26 C.	46·9 992	47·9 992	49 992	50 991	51 991	52 991	53 991	54 991	55·1 991	56·1 991
80·6 27 C.	36·1 992	37·2 992	38·2 992	39·3 992	40·3 992	41·4 992	42·4 992	43·4 991	44·5 991	45·5 991	80·6 27 C.	46·5 991	47·6 991	48·6 991	49·6 991	50·7 990	51·7 990	52·7 990	53·7 990	54·8 990	55·8 990
82·4 28 C.	35·7 992	36·8 992	37·8 992	38·9 991	39·9 991	41 991	42 991	43 991	44·1 991	45·1 990	82·4 28 C.	46·1 990	47·2 990	48·2 990	49·2 990	50·3 990	51·3 990	52·3 990	53·3 989	54·4 989	55·4 989
84·2 29 C.	35·3 991	36·3 991	37·4 991	38·5 991	39·5 991	40·6 990	41·6 990	42·6 990	43·7 990	44·7 990	84·2 29 C.	45·7 990	46·8 989	47·8 989	48·9 989	49·9 989	51 989	52 989	53 989	54 989	55 988
86·0 30 C.	34·9 991	35·9 991	37 990	38·1 990	39·1 990	40·2 990	41·2 990	42·3 989	43·3 989	44·3 989	86·0 30 C.	45·4 989	46·4 989	47·5 989	48·5 988	49·6 988	50·6 988	51·6 988	52·6 988	53·6 988	54·7 988

TABLE I.—Continued.

Temp Fahr.	Observed per centage of the Alcoholometer.										Temp. Fahr.	Observed per centage of the Alcoholometer.									
	61 p.cent.	62 p.cent.	63 p.cent.	64 p.cent.	65 p.cent.	66 p.cent.	67 p.cent.	68 p.cent.	69 p.cent.	70 p.cent.		71 p.cent.	72 p.cent.	73 p.cent.	74 p.cent.	75 p.cent.	76 p.cent.	77 p.cent.	78 p.cent.	79 p.cent.	80 p.cent.
32·0° 0° C.	66 1013	67 1013	68 1013	68·9 1013	69·9 1013	70·8 1013	71·8 1013	72·7 1013	73·7 1014	74·7 1014	32·0° 0° C.	75·6 1014	76·6 1014	77·6 1014	78·6 1014	79·5 1014	80·5 1014	81·5 1014	82·4 1014	83·3 1014	84·3 1014
33·8 1 C.	65·7 1012	66·7 1012	67·7 1012	68·6 1012	69·6 1012	70·5 1012	71·5 1012	72·4 1012	73·4 1013	74·3 1013	33·8 1 C.	75·3 1013	76·3 1013	77·3 1013	78·3 1013	79·2 1013	80·2 1013	81·2 1013	82·1 1013	83·1 1013	84 1013
35·6 2 C.	65·3 1011	66·3 1011	67·3 1011	68·3 1011	69·3 1011	70·2 1011	71·2 1011	72·1 1012	73·1 1012	74 1012	35·6 2 C.	75 1012	76 1012	77 1012	78 1012	78·9 1012	79·9 1012	80·9 1012	81·9 1012	82·8 1012	83·7 1012
37·4 3 C.	65 1010	66 1010	67 1010	68 1010	68·9 1010	69·9 1011	70·8 1011	71·8 1011	72·8 1011	73·7 1011	37·4 3 C.	74·7 1011	75·7 1011	76·7 1011	77·7 1011	78·6 1011	79·6 1011	80·6 1011	81·6 1011	82·5 1011	83·5 1011
39·2 4 C.	64·7 1009	65·7 1009	66·6 1009	67·6 1010	68·6 1010	69·5 1010	70·5 1010	71·5 1010	72·5 1010	73·4 1010	39·2 4 C.	74·4 1010	75·3 1010	76·3 1010	77·3 1010	78·3 1010	79·3 1010	80·3 1010	81·3 1010	82·2 1010	83·2 1010
41·0 5 C.	64·3 1009	65·3 1009	66·3 1009	67·3 1009	68·3 1009	69·2 1009	70·2 1009	71·2 1009	72·2 1009	73·1 1009	41·0 5 C.	74·1 1009	75 1009	76 1009	77 1009	78 1009	79 1009	80 1009	81 1009	81·9 1010	82·9 1010
42·8 6 C.	64 1008	65 1008	66 1008	67 1008	68 1008	68·9 1008	69·9 1008	70·9 1008	71·9 1008	72·8 1008	42·8 6 C.	73·8 1008	74·7 1008	75·7 1008	76·7 1008	77·7 1008	78·7 1008	79·7 1008	80·7 1008	81·6 1008	82·6 1009
44·6 7 C.	63·7 1007	64·7 1007	65·7 1007	66·7 1007	67·6 1007	68·6 1007	69·6 1007	70·6 1007	71·5 1007	72·5 1007	44·6 7 C.	73·5 1007	74·4 1007	75·4 1007	76·4 1007	77·4 1007	78·4 1007	79·4 1007	80·4 1007	81·4 1007	82·3 1008
46·4 8 C.	63·4 1006	64·4 1006	65·4 1006	66·4 1006	67·3 1006	68·3 1006	69·3 1006	70·2 1006	71·2 1006	72·2 1006	46·4 8 C.	73·2 1006	74·1 1006	75·1 1006	76·1 1006	77·1 1006	78·1 1006	79·1 1007	80·1 1007	81·1 1007	82 1007
48·2 9 C.	63 1005	64 1005	65 1005	66 1005	67 1005	67·9 1005	68·9 1005	69·9 1005	70·9 1005	71·9 1005	48·2 9 C.	72·9 1005	73·8 1005	74·8 1005	75·8 1005	76·8 1005	77·8 1005	78·8 1006	79·8 1006	80·8 1006	81·7 1006
50·0 10 C.	62·7 1004	63·7 1004	64·7 1004	65·7 1004	66·7 1004	67·6 1004	68·6 1004	69·6 1004	70·6 1004	71·6 1004	50·0 10 C.	72·6 1004	73·5 1004	74·5 1005	75·5 1005	76·5 1005	77·5 1005	78·5 1005	79·5 1005	80·5 1005	81·5 1005
51·8 11 C.	62·4 1003	63·4 1003	64·4 1003	65·4 1003	66·4 1003	67·3 1003	68·3 1003	69·3 1004	70·3 1004	71·3 1004	51·8 11 C.	72·3 1004	73·2 1004	74·2 1004	75·2 1004	76·2 1004	77·2 1004	78·2 1004	79·2 1004	80·2 1004	81·2 1004
53·6 12 C.	62 1002	63 1002	64 1002	65 1002	66 1002	67 1002	68 1003	69 1003	70 1003	71 1003	53·6 12 C.	72 1003	72·9 1003	73·9 1003	74·9 1003	75·9 1003	76·9 1003	77·9 1003	78·9 1003	79·9 1003	80·9 1003
55·4 13 C.	61·7 1002	62·7 1002	63·7 1002	64·7 1002	65·7 1002	66·7 1002	67·7 1002	68·7 1002	69·6 1002	70·6 1002	55·4 13 C.	71·6 1002	72·6 1002	73·6 1002	74·6 1002	75·6 1002	76·6 1002	77·6 1002	78·6 1002	79·6 1002	80·6 1002
57·2 14 C.	61·3 1001	62·3 1001	63·3 1001	64·3 1001	65·3 1001	66·3 1001	67·3 1001	68·3 1001	69·3 1001	70·3 1001	57·2 14 C.	71·3 1001	72·3 1001	73·3 1001	74·3 1001	75·3 1001	76·3 1001	77·3 1001	78·3 1001	79·3 1001	80·3 1001
59·0 15 C.	61 1000	62 1000	63 1000	64 1000	65 1000	66 1000	67 1000	68 1000	69 1000	70 1000	59·0 15 C.	71 1000	72 1000	73 1000	74 1000	75 1000	76 1000	77 1000	78 1000	79 1000	80 1000
60·8 16 C.	60·6 999	61·7 999	62·7 999	63·7 999	64·7 999	65·7 999	66·7 999	67·7 999	68·7 999	69·7 999	60·8 16 C.	70·7 999	71·7 999	72.7 999	73·7 999	74·7 999	75·7 999	76·7 999	77·7 999	78·7 999	79·7 999
62·6 17 C.	60·3 998	61·3 998	62·3 998	63·3 998	64·3 998	65·3 998	66·3 998	67·3 998	68·3 998	69·3 998	62·6 17 C.	70·3 998	71·3 998	72·3 998	73·3 998	74·3 998	75·4 998	76·4 998	77·4 998	78·4 998	79·4 998
64·4 18 C.	59·9 997	61 997	62 997	63 997	64 997	65 997	66 997	67 997	68 997	69 997	64·4 18 C.	70 997	71 997	72 997	73 997	74 997	75·1 997	76·1 997	77·1 997	78·1 997	79·1 997
66·2 19 C.	59·6 997	60·6 997	61·6 997	62·7 997	63·7 997	64·7 997	65·7 997	66·7 997	67·7 996	68·7 996	66·2 19 C.	69·7 996	70·7 996	71·7 996	72·7 996	73·7 996	74·7 996	75·8 996	76·8 996	77·8 996	78·8 996
68·0 20 C.	59·2 996	60·3 996	61·3 996	62·3 996	63·3 996	64·3 996	65·4 996	66·4 996	67·4 996	68·4 996	68·0 20 C.	69·4 996	70·4 996	71·4 995	72·4 995	73·4 995	74·4 995	75·5 995	76·5 995	77·5 995	78·5 995
69·8 21 C.	58·9 995	59·9 995	61 995	62 995	63 995	64 995	65 995	66 995	67 995	68·1 995	69·8 21 C.	69·1 995	70·1 995	71·1 995	72·1 994	73·1 994	74·1 994	75·2 994	76·2 994	77·2 994	78·2 994
71·6 22 C.	58·5 994	59·5 994	60·6 994	61·6 994	62·7 994	63·7 994	64·7 994	65·7 994	66·7 994	67·8 994	71·6 22 C.	68·8 994	69·8 994	70·8 994	71·8 994	72·8 993	73·8 993	74·8 993	75·9 993	76·9 993	77·9 993
73·4 23 C.	58·1 993	59·2 993	60·2 993	61·3 993	62·3 993	63·3 993	64·3 993	65·4 993	66·4 993	67·4 993	73·4 23 C.	68·4 993	69·4 993	70·5 993	71·5 993	72·5 992	73·5 992	74·5 992	75·5 992	76·6 992	77·6 992
75·2 24 C.	57·8 992	58·9 992	59·9 992	61 992	62 992	63 992	64 992	65 992	66 992	67·1 992	75·2 24 C.	68·1 992	69·1 992	70·1 992	71·2 992	72·2 992	73·2 992	74·2 992	75·2 991	76·3 991	77·3 991
77·0 25 C.	57·5 992	58·5 992	59·5 992	60·6 991	61·6 991	62·6 991	63·7 991	64·7 991	65·7 991	66·7 991	77·0 25 C.	67·8 991	68·8 991	69·8 991	70·8 991	71·8 991	72·8 991	73·9 991	74·9 991	76 991	77 991
78·8 26 C.	57·1 991	58·1 991	59·2 991	60·2 991	61·3 990	62·3 990	63·3 990	64·3 990	65·3 990	66·4 990	78·8 26 C.	67·4 990	68·4 990	69·5 990	70·5 990	71.5 990	72·5 990	73·6 990	74·6 990	75·6 990	76·7 990
80·6 27 C.	56·8 990	57·8 990	58·9 990	59·9 990	60·9 990	61·9 990	63 989	64 989	65 989	66 989	80·6 27 C.	67·1 989	68·1 989	69·2 989	70·2 989	71·2 989	72·2 989	73·3 989	74·3 989	75·3 989	76·3 989
82·4 28 C.	56·4 989	57·5 989	58·5 989	59·5 989	60·6 989	61·6 989	62·6 989	63·7 989	64·7 989	65·7 988	82·4 28 C.	66·8 988	67·8 988	68·8 988	69·9 988	70·9 988	71·9 988	73 988	74 988	75 988	76 988
84·2 29 C.	56 988	57·1 988	58·1 988	59·2 988	60·2 988	61·2 988	62·3 988	63·3 988	64·3 988	65·4 988	84·2 29 C.	66·4 988	67·4 987	68·5 987	69·5 987	70·6 987	71·6 987	72·6 987	73·7 987	74·7 987	75·7 987
86·0 30 C.	55·7 988	56·7 987	57·8 987	58·8 987	59·9 987	60·9 987	61·9 987	63 987	64 987	65 987	86·0 30 C.	66·1 987	67·1 987	68·2 986	69·2 986	70·3 986	71·3 986	72·3 986	73·3 986	74·4 986	75·4 986

TABLE I.—Concluded.

Temp Fahr.	Observed per centage of the Alcoholometer.									
	81 p.cent.	82 p.cent.	83 p.cent.	84 p.cent.	85 p.cent.	86 p.cent.	87 p.cent.	83 p.cent.	89 p.cent.	90 p.cent.
32·0° 0° C.	85·2 1014	86·2 1014	87·1 1014	88 1014	88·9 1014	89·9 1015	90·8 1015	91·7 1015	92·6 1015	93·6 1015
33·8 1 C.	85 1013	85·9 1013	86·8 1013	87·8 1013	88·7 1013	89·6 1014	90·5 1014	91·5 1014	92·4 1014	93·3 1014
35·6 2 C.	84·7 1012	85·6 1012	86·6 1012	87·5 1012	88·5 1012	89·4 1013	90·3 1013	91·2 1013	92·2 1013	93·1 1013
37·4 3 C.	84·4 1011	85·4 1011	86·3 1011	87·3 1011	88·2 1011	89·2 1012	90·1 1012	91 1012	91·9 1012	92·9 1012
39·2 4 C.	84·2 1011	85·1 1011	86·1 1011	87 1011	87·9 1011	88·9 1011	89·8 1011	90·8 1011	91·7 1011	92·7 1011
41·0 5 C.	83·9 1010	84·8 1010	85·8 1010	86·7 1010	87·7 1010	88·6 1010	89·6 1010	90·5 1010	91·5 1010	92·4 1010
42·8 6 C.	83·6 1009	84·5 1009	85·5 1009	86·5 1009	87·4 1009	88·4 1009	89·3 1009	90·2 1009	91·2 1009	92·2 1009
44·6 7 C.	83·3 1008	84·2 1008	85·2 1008	86·2 1008	87·2 1008	88·1 1008	89·1 1008	90 1008	91 1008	91·9 1008
46·4 8 C.	83 1007	84 1007	85 1007	85·9 1007	86·9 1007	87·9 1007	88·8 1007	89·8 1007	90·7 1007	91·7 1007
48·2 9 C.	82·7 1006	83·7 1006	84·7 1006	85·7 1006	86·6 1006	87·6 1006	88·6 1006	89·5 1006	90·5 1006	91·5 1006
50·0 10 C.	82·4 1005	83·4 1005	84·4 1005	85·4 1005	86·4 1005	87·4 1005	88·3 1005	89·3 1005	90·2 1005	91·2 1005
51·8 11 C.	82·2 1004	83·1 1004	84·1 1004	85·1 1004	86·1 1004	87·1 1004	88 1004	89 1004	90 1004	91 1004
53·6 12 C.	81·9 1003	82·9 1003	83·9 1003	84·8 1003	85·8 1003	86·8 1003	87·8 1003	88·7 1003	89·7 1003	90·7 1003
55·4 13 C.	81·6 1002	82·6 1002	83·6 1002	84·6 1002	85·5 1002	86·5 1002	87·5 1002	88·5 1002	89·5 1002	90·5 1002
57·2 14 C.	81·3 1001	82·3 1001	83·3 1001	84·3 1001	85·3 1001	86·3 1001	87·3 1001	88·2 1001	89·2 1001	90·2 1001
59·0 15 C.	81 1000	82 1000	83 1000	84 1000	85 1000	86 1000	87 1000	88 1000	89 1000	90 1000
60·8 16 C.	80·7 999	81·7 999	82·7 999	83·7 999	84·7 999	85·7 999	86·7 999	87·7 999	88·7 999	89·7 999
62·6 17 C.	80·4 998	81·4 998	82·4 998	83·4 998	84·4 998	85·4 998	86·4 998	87·4 998	88·4 998	89·5 998
64·4 18 C.	80·1 997	81·1 997	82·1 997	83·1 997	84·1 997	85·2 997	86·2 997	87·2 997	88·2 997	89·2 997
66·2 19 C.	79·8 996	80·8 996	81·9 996	82·9 996	83·9 996	84·9 996	85·9 996	86·9 996	87·9 996	88·9 996
68·0 20 C.	79·5 995	80·5 995	81·6 995	82·6 995	83·6 995	84·6 995	85·6 995	86·6 995	87·7 995	88·7 995
69·8 21 C.	79·2 994	80·2 994	81·3 994	82·3 994	83·3 994	84·3 994	85·3 994	86·4 994	87·4 994	88·4 994
71·6 22 C.	78·9 993	79·9 993	81 993	82 993	83 993	84 993	85 993	86·1 993	87·1 993	88·2 993
73·4 23 C.	78·6 992	79·6 992	80·7 992	81·7 992	82·7 992	83·8 992	84·8 992	85·8 992	86·8 992	87·9 992
75·2 24 C.	78·3 991	79·3 991	80·4 991	81·4 991	82·4 991	83·5 991	84·5 991	85·5 991	86·5 991	87·6 991
77·0 25 C.	78 991	79 991	80·1 990	81·1 990	82·1 990	83·2 990	84·2 990	85·2 990	86·3 990	87·4 990
78·8 26 C.	77·7 990	78·7 989	79·8 989	80·8 989	81·8 989	82·9 989	83·9 989	84·9 989	86 989	87·1 989
80·6 27 C.	77·4 989	78·4 988	79·5 988	80·5 988	81·5 988	82·6 988	83·6 988	84·7 988	85·7 988	86 8 988
82·4 28 C.	77·1 988	78·1 988	79·2 987	80·2 987	81·2 987	82·3 987	83·3 987	84·4 987	85·4 987	86·5 987
84·2 29 C.	76·7 987	77·8 987	78·9 987	79·9 986	80·9 986	82 986	83 986	84·1 986	85·1 986	86·2 986
86·0 30 C.	76·4 986	77·7 986	78·6 986	79·6 986	80·6 985	81·7 985	82·7 985	83·8 985	84·9 985	86 985

Temp. Fahr.	Observed per centage of the Alcoholometer.									
	91 p.cent.	92 p.cent.	93 p.cent.	94 p.cent.	95 p.cent.	96 p.cent.	97 p.cent.	98 p.cent.	99 p.cent.	100 p.cent.
32·0° 0° C.	94·5 1015	95·3 1015	96·2 1015	97·1 1015	98 1015	98·8 1015	99·7 1016			
33·8 1 C.	94·3 1014	95·1 1014	96 1014	96·9 1014	97·8 1014	98·6 1014	99·5 1014			
35·6 2 C.	94 1013	94·9 1013	95·8 1013	96·7 1013	97·6 1013	98·5 1013	99·3 1014			
37·4 3 C.	93·8 1012	94·7 1012	95·6 1012	96·5 1012	97·4 1012	98·3 1012	99·2 1012	1012		
39·2 4 C.	93·6 1011	94·5 1011	95·4 1011	96·3 1011	97·2 1011	98·1 1011	99 1011	99·9 1011		
41·0 5 C.	93·4 1010	94·3 1010	95·2 1010	96·1 1010	97 1010	97·9 1010	98·8 1010	99·7 1010		
42·8 6 C.	93·1 1009	94·1 1009	95 1009	95·9 1009	96·8 1009	97·8 1009	98·7 1009	99·6 1009		
44·6 7 C.	92·9 1008	93·9 1008	94·8 1008	95·7 1008	96·6 1008	97·6 1008	98·5 1008	99·4 1008		
46·4 8 C.	92·7 1007	93·6 1007	94·6 1007	95·5 1007	96·4 1007	97·4 1007	98·3 1007	99·2 1007	1007	
48·2 9 C.	92·5 1006	93·4 1006	94·4 1006	95·3 1006	96·2 1006	97·2 1006	98·1 1006	99·1 1006	100 1006	
50·0 10 C.	92·2 1005	93·2 1005	94·2 1005	95·1 1005	96 1005	97 1005	98 1005	98·9 1005	99·9 1005	
51·8 11 C.	92 1004	92·9 1004	93·9 1004	94·9 1004	95·8 1004	96·8 1004	97·8 1004	98·7 1004	99·7 1004	
53·6 12 C.	91·7 1003	92·7 1003	93·7 1003	94·7 1003	95·6 1003	96·6 1003	97·6 1003	98·5 1003	99·5 1003	
55·4 13 C.	91·5 1002	92·5 1002	93·5 1002	94·4 1002	95·4 1002	96·4 1002	97·4 1002	98·4 1002	99·3 1002	
57·2 14 C.	91·2 1001	92·2 1001	93·2 1001	94·2 1001	95·2 1001	96·2 1001	97·2 1001	98·2 1001	99·2 1001	
59·0 15 C.	91 1000	92 1000	93 1000	94 1000	95 1000	96 1000	97 1000	98 1000	99 1000	100 1000
60·8 16 C.	90·8 999	91·8 999	92.8 999	93·8 999	94·8 999	95·8 999	96·8 999	97·8 999	98·8 999	99·8 999
62·6 17 C.	90·5 998	91·5 998	92·6 998	93·6 998	94·6 998	95·6 998	96·6 998	97·6 998	98·7 998	99·7 998
64·4 18 C.	90·2 997	91·3 997	92·3 997	93·3 997	94·3 997	95·4 997	96·4 997	97·4 997	98·5 997	99·5 997
66·2 19 C.	90 996	91·1 996	92·1 996	93·1 996	94·1 996	95·2 996	96·2 996	97·3 996	98·3 996	99·3 996
68·0 20 C.	89·7 995	90·8 995	91·8 995	92·9 995	93·9 995	95 995	96 995	97·1 995	98·1 995	99·1 995
69·8 21 C.	89·5 994	90·5 994	91·6 994	92·6 994	93·7 994	94·7 994	95·8 994	96·9 994	97·9 994	99 994
71·6 22 C.	89·2 993	90·2 993	91·3 993	92·4 993	93·4 993	94·5 993	95·6 993	96·7 993	97·7 993	98·8 993
73·4 23 C.	89 992	90 992	91·1 992	92·1 992	93·2 992	94·3 992	95·4 992	96·5 992	97·5 992	98·6 992
75·2 24 C.	88·7 991	89·7 991	90·8 991	91·9 991	93 991	94·1 991	95·2 991	96·2 991	97·3 991	98·4 991
77·0 25 C.	88·4 990	89·5 990	90·6 990	91·6 990	92·7 990	93·8 990	94·9 990	96 990	97·1 990	98·2 990
78·8 26 C.	88·2 989	89·2 989	90·3 989	91·4 989	92.5 989	93·6 989	94·7 989	95·8 989	96·9 989	98·1 989
80·6 27 C.	87·9 988	89 988	90·1 988	91·1 988	92·2 988	93·4 988	94·5 988	95·6 987	96·7 987	97·9 987
82·4 28 C.	87·6 987	88·7 987	89·8 987	90·9 987	92 987	93·1 987	94·3 987	95·4 986	96·5 986	97·7 986
84·2 29 C.	87·3 986	88·4 986	89·5 986	90·6 986	91·7 986	92·9 986	94·1 986	95·2 986	96·3 985	97·5 985
86·0 30 C.	87·1 985	88·2 985	89·3 985	90·4 985	91·5 985	92·7 985	93·8 985	95 985	96·1 984	97·3 984

The second of GAY-LUSSAC's tables corresponds to Table VII. of TRALLES, and gives directly, but less accurately, that which by the former table is only obtained by a calculation, namely, the per centage by volume of the liquid at any temperature at which it is tested, from the observed per cent. Thus, if, as in the former example, the alcoholometer indicated 59 per cent. in the liquid at 77°, the observed per cent., 59, is sought for in the upper horizontal column, and in the vertical column below it that number is then taken which is in the same horizontal column with the observed temperature, 77°, in the left-hand column, which in this case is 55, or the liquid at the observed temperature of 77° contains 55 volumes of anhydrous alcohol.

TABLE II.

ALCOHOLOMETRIC TABLE OF GAY-LUSSAC,

To find directly the per centage of absolute alcohol of a liquid at any temperature—its richness—from the observed per centage at the same temperature.

Temp.		Observed per centage of the Alcoholometer.																			
Fahr.	Cent.	1 p.cent.	2 p.cent.	3 p.cent.	4 p.cent.	5 p.cent.	6 p.cent.	7 p.cent.	8 p.cent.	9 p.cent.	10 p.cent.	11 p.cent.	12 p.cent.	13 p.cent.	14 p.cent.	15 p.cent.	16 p.cent.	17 p.cent.	18 p.cent.	19 p.cent.	20 p.cent.
32·0	0	1·3	2.4	3·4	4·4	5·4	6·5	7 5	8·6	9·7	10·9	12·2	13·4	14·7	16·1	17·5	19	20·4	21·7	23	24·3
33·8	1											—	13·4	14·7	16	17·3	18·7	20·1	21·4	22·7	24
35·6	2											—	13·4	14·7	16	17·2	18·6	19·9	21·2	22·4	23·7
37·4	3											—	13·3	14·6	15·9	17·1	18·3	19·7	20·9	22·1	23·4
39·2	4											—	13·3	14·5	15·8	16·9	18·1	19·4	20·7	21·9	23·1
41·0	5	1·4	2·5	3·5	4·5	5·5	6·6	7·7	8·7	9·8	10·9	12·1	13·2	14·4	15·7	16·8	18	19·2	20·5	21·6	22·8
42·8	6											—	13·1	14·3	15·6	16·7	17·8	19	20·3	21·4	22·5
44·6	7											—	13	14·2	15·4	16·6	17·7	18·8	20	21	22·1
46·4	8											—	13	14·1	15·3	16·4	17·5	18·6	19·7	20·7	21·8
48·2	9											—	12·9	14	15·1	16·2	17·3	18·4	19·5	20·5	21·6
50 0	10	1·4	2·4	3·4	4·5	5·5	6·5	7·5	8·5	9·5	10·6	11·7	12·7	13·8	14·9	16	17	18·1	19·2	20·2	21·3
51 8	11	1·3	2·4	3·4	4·4	5·4	6·4	7·4	8·4	9·4	10·5	11·6	12·6	13·6	14·7	15·8	16·8	17·9	19	20	21
53·6	12	1·2	2·3	3·3	4·3	5·3	6·3	7·3	8·3	9·3	10·4	11·5	12·5	13·5	14·6	15·6	16·6	17·6	18·7	19·7	20·7
55·4	13	1·2	2·2	3·2	4·2	5·2	6·2	7·2	8·2	9·2	10·3	11·4	12·4	13·4	14·4	15·4	16·4	17·4	18·5	19·5	20·5
57·2	14	1·1	2·1	3·1	4·1	5·1	6·1	7·1	8·1	9·1	10·2	11·2	12·2	13·2	14·2	15·2	16·2	17·2	18·2	19·2	20·2
59·0	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
60·8	16	0·9	1·9	2·9	3·9	4·9	5·9	6 9	7·9	8·9	9·9	10·9	11·9	12·9	13·9	14·9	15·9	16·9	17·8	18·7	19·7
62·6	17	0·8	1·8	2·8	3·8	4·8	5·8	6·8	7·8	8·8	9·8	10·8	11·7	12·7	13·7	14·7	15·6	16·6	17·5	18·4	19·4
64·4	18	0·7	1·7	2·7	3·7	4·7	5·7	6·7	7·7	8·7	9·7	10·7	11·6	12·5	13·5	14·5	15·4	16·3	17·3	18·2	19·1
66·2	19	0·6	1·6	2·6	3·6	4·5	5·5	6·5	7·5	8·5	9·5	10·5	11·4	12·4	13·3	14·3	15·2	16·1	17	17·9	18·8
68·0	20	0·5	1·5	2·4	3·4	4·4	5·4	6·4	7·3	8·3	9·3	10·3	11·2	12·2	13·1	14	14·9	15·8	16·7	17·6	18·5
69·8	21	0·4	1·4	2·3	3·3	4·3	5·2	6·2	7·1	8·1	9·1	10·1	11	11·9	12·8	13·7	14·6	15·5	16·4	17·3	18·2
71·6	22	0·3	1·3	2·2	3·2	4·1	5·1	6·1	7	7·9	8·9	9·9	10·8	11·7	12·6	13·5	14·4	15·3	16·2	17	17·9
73·4	23	0·1	1·1	2·1	3·1	4	4·9	5·9	6·8	7·8	8·7	9·7	10·6	11·5	12·4	13·3	14·1	15	15·9	16·7	17·6
75·2	24	0·0	1	1·9	2·9	3·8	4·8	5·8	6·7	7·6	8 5	9·5	10·4	11·3	12·2	13·1	13·9	14·8	15·7	16·5	17·4
77·0	25	—	0·8	1·7	2·7	3·6	4·6	5·5	6·5	7·4	8·3	9·3	10·2	11·1	12	12·8	13·6	14·5	15·4	16·2	17·1
78·8	26	—	0·7	1·6	2·6	3·5	4·4	5·4	6·3	7 2	8·1	9	9·9	10·8	11·7	12·6	13·4	14·2	15·1	15·9	16·7
80·6	27	—	0·5	1·5	2·4	3·3	4·3	5·2	6·1	7	7·9	8·8	9·7	10·6	11·5	12·3	13·1	13·9	14·8	15·6	16·4
82·4	28	—	0·3	1·3	2·2	3·1	4·1	5	5·9	6·8	7·7	8·6	9·5	10·3	11·2	12	12·8	13·6	14·4	15·2	16
84·2	29	—	0·1	1·1	2	2·9	3·9	4·8	5·7	6·6	7·5	8·4	9·2	10·1	11	11·7	12·5	13·3	14·1	14·9	15 7
86·0	30	—	0·0	0·9	1·9	2·8	3·7	4·6	5·5	6·4	7·3	8·1	9	9·8	10·7	11·5	12·3	13	13·8	14·6	15·4

Temp																					
Fahr.	Cent.	21 p.cent.	22 p.cent.	23 p.cent.	24 p.cent.	25 p.cent.	26 p.cent.	27 p.cent.	28 p.cent.	29 p.cent.	30 p.cent.	31 p.cent.	32 p.cent.	33 p.cent.	34 p.cent.	35 p.cent.	36 p.cent.	37 p.cent.	38 p.cent.	39 p.cent.	40 p.cent.
32·0	0	25·7	27·1	28·5	29·9	31·1	32·3	33·4	34·5	35·6	36·6	37·6	38·5	39·6	40·6	41·5	42·5	43·5	44·4	45·4	46·4
33·8	1	25·4	26·8	28·1	29·4	30·6	31·8	32·9	34	35·1	36·1	37·1	38·1	39·1	40·1	41·2	42·2	43·1	44·1	45	46
35·6	2	25	26·4	27·6	28·9	30·2	31·4	32·5	33·5	34·6	35·6	36·7	37·7	38·7	39·7	40·7	41·7	42·7	43·7	44·6	45·5
37·4	3	24·7	26	27·3	28·6	29·8	31	32·1	33·1	34·1	35·2	36·2	37·3	38·3	39·3	40·3	41·3	42·3	43·2	44·2	45·2
39·2	4	24·4	25·7	26·9	28·1	29·3	30·6	31·6	32·7	33·7	34·7	35·7	36·7	37·7	38·8	39·8	40·8	41·8	42·8	43·8	44·8
41·0	5	24·1	25·3	26·5	27·7	28·9	30·1	31·2	32·3	33·3	34·3	35·3	36·3	37·3	38·3	39·3	40·3	41·4	42·4	43·4	44·4
42·8	6	23·7	25	26·1	27·3	28·5	29·7	30·8	31·8	32·8	33·8	34·9	35·9	36·9	37·9	38·9	39·9	40·9	41·9	42·9	43·9
44·6	7	23·4	24·7	25·8	27	28·1	29·3	30·3	31·3	32·3	33·3	34·3	35·4	36·4	37·4	38·4	39·4	40·4	41·4	42·4	43·4
46·4	8	23	24·2	25·4	26·6	27·7	28·9	29·9	30·9	31·9	32·9	33·9	34·9	35·9	36·9	38	39	40	41	42	43
48·2	9	22·7	23·9	25	26·2	27·3	28·5	29·5	30·5	31·5	32·5	33·5	34·5	35·5	36·5	37·5	38·6	39·6	40·6	41·6	42·6
50·0	10	22·4	23·5	24·6	25·8	26·9	28	29·1	30·1	31·1	32·1	33·1	34·1	35·1	36·1	37·1	38·1	39·1	40·1	41·1	42·1
51·8	11	22·1	23·2	24·3	25·4	26·5	27·7	28·7	29·7	30·7	31·7	32·7	33·7	34·7	35·7	36·7	37·7	38·7	39·7	40·7	41·7
53·6	12	21·8	22·9	24	25·1	26·1	27·2	28·2	29·2	30·2	31·2	32·2	33·2	34·3	35·3	36·3	37·3	38·3	39·3	40·3	41·3
55·4	13	21 5	22·6	23·7	24·7	25·7	26·8	27·8	28·8	29·8	30·8	31·8	32·8	33·8	34·8	35·8	36·8	37·8	38·8	39·8	40·9
57·2	14	21·2	22·3	23·3	24·3	25·3	26·4	27·4	28·4	29·4	30·4	31·4	32·4	33·4	34·4	35·4	36·4	37·4	38·4	39·4	40·4
59·0	15	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
60·8	16	20·7	21·7	22·7	23·7	24·7	25·7	26·6	27·6	28·6	29·6	30·6	31·6	32·5	33·5	34·5	35·5	36·5	37·5	38·5	39·5
62·6	17	20·4	21·4	22·4	23·4	24·4	25·4	26·3	27·3	28·2	29·2	30·2	31·2	32·1	33·1	34·1	35·1	36·1	37·1	38·1	39·1
64·4	18	20·1	21·1	22	23	24	25	25·9	26·9	27·8	28·8	29·8	30·8	31·7	32·6	33.6	34·6	35·6	36·6	37·6	38·6
66·2	19	19·8	20·8	21·7	22·7	23·6	24·6	25·5	26·4	27·3	28·3	29·3	30·3	31·2	32·2	33·2	34·2	35·2	36·2	37·2	38·2
68·0	20	19·5	20·5	21·4	22·4	23·3	24·3	25·2	26·1	27	27·9	28·9	29·9	30·8	31·8	32·8	33·8	34·8	35·8	36·8	37·8
69·8	21	19·1	20·1	21·1	22·1	22·9	23·9	24·8	25·6	26·6	27·5	28·5	29·5	30·4	31·4	32·4	33·4	34·4	35·4	36·4	37·4
71·6	22	18·8	19·8	20·7	21·6	22·5	23·5	24·3	25·2	26·2	27·1	28·1	29·1	30	31	32	33	34	35	36	36·9
73·4	23	18·5	19·4	20·3	21·3	22·2	23·1	24	24·9	25·8	26·7	27·7	28·7	29·6	30·6	31·6	32·6	33·5	34·5	35·5	36·5
75·2	24	18·2	19·1	20	21	21·8	22·7	23·6	24·5	25·4	26·3	27·3	28·3	29·2	30·2	31·1	32·1	33·1	34·1	35·1	36·1

TABLE II.—Continued.

Temp.		Observed per centage of the Alcoholometer.																			
Fahr.	Cent.	21 p.cent.	22 p.cent.	23 p.cent.	24 p.cent.	25 p.cent.	26 p.cent.	27 p.cent.	28 p.cent.	29 p.cent.	30 p.cent.	31 p.cent.	32 p.cent.	33 p.cent.	34 p.cent.	35 p.cent.	36 p.cent.	37 p.cent.	38 p.cent.	39 p.cent.	40 p.cent.
77·0	25	17·9	18·8	19·7	20·6	21·5	22·4	23·2	24·2	25·1	26	26·9	27·9	28·8	29·7	30·7	31·7	32·7	33·7	34·7	35·7
78·8	26	17·6	18·5	19·4	20·3	21·2	22·1	22·9	23·8	24·7	25·6	26·5	27·5	28·4	29·3	30·3	31·3	32·3	33·3	34·3	35·3
80·6	27	17·3	18·2	19·1	20	20·8	21·7	22·6	23·5	24·3	25·2	26·1	27·1	27·9	28·9	29·9	30·9	31·9	32·9	33·9	34·8
82·4	28	16·9	17·9	18·8	19·6	20·5	21·4	22·2	23·1	23·9	24·8	25·7	26·6	27·5	28·5	29·5	30·5	31·5	32·5	33·5	34·4
84·2	29	16·6	17·5	18·4	19·3	20·2	21	21·8	22·7	23·6	24·4	25·2	26·2	27·1	28·1	29·1	30·1	31·1	32·1	33·1	34
86·0	30	16·3	17·2	18·1	19	19·8	20·7	21·5	22·4	23·2	24	24·9	25·8	26·7	27·7	28·7	29·7	30·7	31·6	32·6	33·6

Temp. Fahr.	Cent.	41 p.cent.	42 p.cent.	43 p.cent.	44 p.cent.	45 p.cent.	46 p.cent.	47 p.cent.	48 p.cent.	49 p.cent.	50 p.cent.	51 p.cent.	52 p.cent.	53 p.cent.	54 p.cent.	55 p.cent.	56 p.cent.	57 p.cent.	58 p.cent.	59 p.cent.	60 p.cent.
32·0	0	47·4	48·4	49·3	50·3	51·3	52·3	53·2	54·1	55·1	56·1	57·1	58	59	59·9	60·9	61·9	62·9	63·9	64·9	65·8
33·8	1	47	48	48·9	49·9	50·8	51·8	52·8	53·7	54·7	55·7	56·7	57·6	58·6	59·6	60·6	61·6	62·5	63·5	64·5	65·5
35·6	2	46·5	47·5	48·5	49·5	50·4	51·4	52·3	53·3	54·3	55·3	56·3	57·2	58·2	59·2	60·2	61·2	62·1	63·1	64·1	65·1
37·4	3	46·2	47·1	48·1	49	50	51	52	52·9	53·9	54·8	55·8	56·8	57·8	58·8	59·8	60·8	61·7	62·7	63·7	64·7
39·2	4	45·8	46·7	47·7	48·7	49·6	50·6	51·5	52·5	53·5	54·5	55·5	56·5	57·4	58·4	59·4	60·3	61·3	62·3	63·3	64·3
41·0	5	45·3	46·2	47·2	48·2	49·2	50·2	51·1	52·1	53·1	54	55	56	57	58	59	60	60·9	61·9	62·9	63·9
42·8	6	44·9	45·8	46·8	47·8	48·8	49·8	50·8	51·7	52·7	53·7	54·7	55·6	56·6	57·5	58·5	59·5	60·5	61·5	62·5	63·5
44·6	7	44·4	45·4	46·4	47·4	48·4	49·4	50·4	51·3	52·3	53·2	54·2	55·2	56·2	57·1	58·1	59·1	60·1	61·1	62·1	63·1
46·4	8	44	45	46	47	47·9	48·9	49·9	50·9	51·9	52·9	53·9	54·9	55·8	56·8	57·8	58·8	59·8	60·8	61·8	62·8
48·2	9	43·6	44·6	45·6	46·6	47·5	48·5	49·5	50·5	51·5	52·5	53·5	54·5	55·4	56·4	57·4	58·4	59·4	60·4	61·4	62·4
50·0	10	43·1	44·1	45·1	46·1	47·1	48·1	49·1	50·1	51·1	52	53	54	55	56	57	58	59	60	61	62
51·8	11	42·7	43·7	44·7	45·7	46·7	47·7	48·7	49·7	50·7	51·7	52·7	53·7	54·6	55·6	56·6	57·6	58·6	59·6	60·6	61·6
53·6	12	42·3	43·3	44·3	45·3	46·3	47·3	48·3	49·3	50·3	51·2	52·2	53·2	54·2	55·2	56·2	57·2	58·2	59·2	60·2	61·2
55·4	13	41·9	42·9	43·9	44·9	45·9	46·9	47·9	48·9	49·9	50·9	51·9	52·8	53·8	54·8	55·8	56·8	57·8	58·8	59·8	60·8
57·2	14	41·4	42·4	43·4	44·4	45·4	46·4	47·4	48·4	49·4	50·4	51·4	52·4	53·4	54·4	55·4	56·4	57·4	58·4	59·4	60·4
59·0	15	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
60·8	16	40·6	41·6	42·6	43·6	44·6	45·6	46·6	47·6	48·6	49·6	50·6	51·6	52·6	53·6	54·6	55·6	56·6	57·6	58·6	59·6
62·6	17	40·1	41·1	42·1	43·1	44·1	45·2	46·2	47·2	48·2	49·2	50·2	51·2	52·2	53·2	54·2	55·2	56·2	57·2	58·2	59·2
64·4	18	39·7	40·7	41·7	42·7	43·7	44·8	45·8	46·8	47·8	48·8	49·8	50·8	51·8	52·8	53·8	54·8	55·8	56·8	57·8	58·8
66·2	19	39·3	40·3	41·3	42·4	43·4	44·4	45·4	46·4	47·4	48·4	49·4	50·4	51·4	52·4	53·4	54·4	55·4	56·4	57·4	58·4
68·0	20	38·9	39·9	40·9	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
69·8	21	38·4	39·4	40·4	41·5	42·5	43·5	44·6	45·6	46·6	47·6	48·6	49·6	50·6	51·6	52·6	53·6	54·6	55·6	56·6	57·6
71·6	22	38	39	40	41·1	42·1	43·1	44·1	45·1	46·1	47·1	48·1	49·1	50·1	51·1	52·2	53·2	54·2	55·2	56·2	57·2
73·4	23	37·6	38·6	39·6	40·6	41·6	42·6	43·6	44·6	45·7	46·7	47·7	48·8	49·8	50·8	51·8	52·8	53·8	54·8	55·8	56·8
75·2	24	37·2	38·2	39·2	40·2	41·2	42·2	43·3	44·3	45·3	46·3	47·3	48·4	49·4	50·4	51·4	52·4	53·4	54·4	55·4	56·4
77·0	25	36·7	37·7	38·7	39·8	40·8	41·9	42·9	43·9	44·9	46	47	48	49	50	51	52	53	54	55	56
78·8	26	36·3	37·3	38·3	39·4	40·4	41·5	42·5	43·5	44·5	45·5	46·5	47·5	48·5	49·5	50·5	51·5	52·5	53·5	54·5	55·6
80·6	27	35·9	36·9	37·9	39	40	41·1	42·1	43·1	44·1	45·1	46·1	47·1	48·1	49·1	50·2	51·2	52·2	53·2	54·2	55·2
82·4	28	35·4	36·5	37·5	38·6	39·6	40·6	41·6	42·6	43·7	44·7	45·7	46·7	47·7	48·7	49·8	50·8	51·8	52·8	53·8	54·8
84·2	29	35	36	37·1	38·1	39·1	40·2	41·2	42·2	43·3	44·3	45·3	46·3	47·3	48·4	49·4	50·4	51·4	52·4	53·4	54·4
86·0	30	34·6	35·6	36·6	37·7	38·7	39·8	40·8	41·8	42·8	43.8	44·9	45·9	47	48	49	50	51	52	53	54

Temp. Fahr.	Cent.	61 p.cent.	62 p.cent.	63 p.cent.	64 p.cent.	65 p.cent.	66 p.cent.	67 p.cent.	68 p.cent.	69 p.cent.	70 p.cent.	71 p.cent.	72 p.cent.	73 p.cent.	74 p.cent.	75 p.cent.	76 p.cent.	77 p.cent.	78 p.cent.	79 p.cent.	80 p.cent.
32·0	0	66·8	67·8	68·8	69·8	70·8	71·7	72·7	73·7	74·7	75·7	76·6	77·6	78·6	79·6	80·6	81·6	82·6	83·6	84·5	85·5
33·8	1	66·5	67·5	68·5	69·4	70·4	71·3	72·3	73·3	74·3	75·3	76·2	77·2	78·2	79·2	80·2	81·2	82·2	83·2	84·2	85·1
35·6	2	66·1	67·1	68·1	69·1	70·1	71	71·9	72·9	73·9	74·9	75·9	76·9	77·9	78·9	79·9	80·9	81·9	82·9	83·8	84·7
37·4	3	65·6	66·6	67·6	68·6	69·6	70·6	71·6	72·6	73·6	74·5	75·5	76·5	77·5	78·5	79·5	80·5	81·5	82·5	83·4	84·4
39·2	4	65·3	66·3	67·3	68·3	69·3	70·2	71·2	72·2	73·2	74·1	75·1	76·1	77·1	78·1	79·1	80·1	81·1	82·1	83	84
41·0	5	64·9	65·9	66·9	67·9	68·9	69·8	70·8	71·8	72·8	73·8	74·8	75·7	76·7	77·7	78·7	79·7	80·7	81·7	82·7	83·7
42·8	6	64·5	65·5	66·5	67·5	68·5	69·5	70·5	71·5	72·5	73·4	74·4	75·3	76·3	77·3	78·3	79·3	80·3	81·3	82·3	83·3
44·6	7	64·1	65·1	66·1	67·1	68·1	69·1	70·1	71·1	72	73	74	75	76	77	78	79	80	81	82	82·9
46·4	8	63·8	64·8	65·8	66·8	67·7	68·7	69·7	70·6	71·6	72·6	73·6	74·6	75·6	76·6	77·6	78·6	79·6	80·6	81·6	82·6
48·2	9	63·4	64·4	65·4	66·4	67·3	68·3	69·3	70·3	71·3	72·3	73·3	74·2	75·2	76·2	77·2	78·2	79·2	80·2	81·2	82·2
50·0	10	63	64	65	66	67	67·9	68·9	69·9	70·9	71·9	72·9	73·9	74·9	75·9	76·9	77·9	78·9	79·9	80·9	81·9
51·8	11	62·6	63·6	64·6	65·6	66·6	67·6	68·6	69·6	70·6	71·6	72·6	73·5	74·5	75·5	76·5	77·5	78·5	79·5	80·5	81·5
53·6	12	62·2	63·2	64·2	65·2	66·2	67·2	68·2	69·2	70·2	71·2	72·2	73·1	74·1	75·1	76·1	77·1	78·1	79·1	80·1	81·1
55·4	13	61·8	62·8	63·8	64·8	65·8	66·8	67·8	68·8	69·8	70·8	71·8	72·8	73 8	74·8	75·8	76·8	77·8	78·8	79·8	80·8
57·2	14	61·4	62·4	63·4	64·4	65·4	66·4	67·4	68·4	69·4	70·4	71·4	72·4	73·4	74·4	75·4	76·4	77·4	78·4	79·4	80·4
59·0	15	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
60·8	16	60·6	61·6	62·6	63·6	64·6	65·6	66·6	67·6	68·6	69·6	70·6	71·6	72·6	73·6	74·6	75·6	76·6	77·6	78·6	79·6
62·6	17	60·2	61·2	62·2	63·2	64·2	65·2	66·3	67·2	68·2	69·2	70·2	71·2	72·2	73·2	74·2	75·2	76·2	77·2	78·2	79·2
64·4	18	59·8	60·8	61·8	62·8	63·8	64·8	65·8	66·8	67·8	68·8	69·8	70·8	71·8	72·8	73·8	74·9	75·9	76·9	77·9	78·9
66·2	19	59·4	60·4	61·4	62·5	63·5	64·5	65·5	66·5	67·5	68·5	69·5	70·5	71·5	72·5	73·5	74·5	75·5	76·5	77·5	78·5
68·0	20	59	60	61	62	63	64	65·1	66·1	67·1	68·1	69·1	70·1	71·1	72·1	73·1	74·1	75·1	76·1	77·1	78·1
69·8	21	58·6	59·6	60·7	61·7	62·7	63·7	64·7	65·7	66·7	67·7	68·7	69·7	70·7	71·7	72·7	73·7	74·7	75·8	76·8	77·8
71·6	22	58·2	59·2	60·3	61·3	62·3	63·3	64·3	65·3	66·3	67·3	68·3	69·3	70·3	71·3	72·3	73·3	74·3	75·4	76·4	77·4
73·4	23	57·8	58·8	59·8	60·9	61·9	62·9	63·9	64·9	65·9	66·9	67·9	68·9	70	71	72	73	74	75	76	77
75·2	24	57·4	58·4	59·4	60·5	61·5	62·5	63·5	64·5	65·5	66·5	67·5	68·5	69·6	70·6	71·6	72·6	73·6	74·6	75·6	76·6
77·0	25	57	58	59	60·1	61·1	62·1	63·1	64·1	65·1	66·1	67·1	68·1	69 2	70·2	71·2	72·2	73·2	74·2	75·3	76·3
78·8	26	56·6	57·6	58·6	59·6	60·7	61·7	62·7	63·7	64·7	65 7	66·7	67·7	68·8	69·8	70·8	71·8	72·8	73·8	74·8	75·9
80·6	27	56·2	57·2	58·3	59·3	60·3	61·3	62·3	63·3	64·3	65·3	66·3	67·3	68·4	69·4	70·4	71·4	72·4	73·4	74·4	75·5
82·4	28	55·8	56·8	57·8	58·8	59·9	60·9	61·9	62·9	63·9	64·9	66	67	68	69·1	70·1	71·1	72·1	73·1	74·1	75·1
84·2	29	55·4	56·4	57·4	58·5	59·5	60·5	61·5	62·5	63·5	64·5	65·6	66·6	67·7	68·7	69·7	70·7	71·7	72·7	73·7	74·7
86·0	30	55	56	57·1	58·1	59·1	60·1	61·1	62·1	63·1	64·1	65·2	66·2	67·3	68·3	69·3	70·3	71·3	72·3	73·3	74·3

TABLE II.—Concluded.

Temp. Fahr.	Temp. Cent.	Observed per centage of the Alcoholometer. 81 p.cent.	82 p.cent.	83 p.cent.	84 p.cent.	85 p.cent.	86 p.cent.	87 p.cent.	88 p.cent.	89 p.cent.	90 p.cent.	91 p.cent.	92 p.cent.	93 p.cent.	94 p.cent.	95 p.cent.	96 p. cent.	97 p. cent.	98 p. cent.	99 p. cent.	100 p. cent.
32·0	0	86·4	87·4	88·3	89·2	90·2	91·2	92·2	93·1	94	95	95·9	96·8	97·7	98·6	99·5	100·3	101·2			
33·8	1	86·1	87	88	89	89·9	90·8	91·8	92·8	93·7	94·6	95·6	96·5	97·4	98·3	99·2	100	100·9			
35·6	2	85·7	86·6	87·6	88·6	89·6	90·5	91·5	92·4	93·4	94·3	95·2	96·1	97	97·9	98·9	99·8	100·7			
37·4	3	85·3	86·3	87·3	88·3	89·2	90·2	91·2	92·1	93	94	94·9	95·8	96·7	97·7	98·6	99·5	100·4			
39·2	4	85	86	87	88	88·9	89·9	90·8	91·8	92·7	93·7	94·6	95·5	96·4	97·4	98·3	99·2	100·1	101		
41·0	5	84·7	85·6	86·6	87·6	88·5	89·5	90·5	91·4	92·4	93·3	94·3	95·2	96·2	97·1	98	98·9	99·8	100·7		
42·8	6	84·3	85·3	86·3	87·3	88·2	89·2	90·1	91	92	93	93·9	94·9	95·9	96·8	97·7	98·7	99·6	100·5		
44·6	7	83·9	84·9	85·9	86·9	87·9	88·8	89·8	90·7	91·7	92·6	93·6	94·6	95·6	96·5	97·4	98·4	99·3	100·2		
46·4	8	83·6	84·6	85·6	86·5	87·5	88·5	89·4	90·4	91·3	92·3	93·3	94·3	95·3	96·2	97·1	98·1	99	99·9		
48·2	9	83·2	84·2	85·2	86·2	87·1	88·1	89·1	90	91	92	93	94	95	95·9	96·8	97·8	98·7	99·7	100	
50·0	10	82·8	83·8	84·8	85·8	86·8	87·8	88·7	89·7	90·7	91·7	92·7	93·7	94·7	95·6	96·5	97·5	98·5	99·4	100·4	
51·8	11	82·5	83·4	84·4	85·4	86·4	87·4	88·4	89·4	90·4	91·4	92·4	93·3	94·3	95·3	96·2	97·2	98·2	99·1	100·1	
53·6	12	82·1	83·1	84·1	85	86	87	88	89	90	91	92	93	94	95	95·9	96·9	97·9	98·8	99·8	
55·4	13	81·8	82·8	83·8	84·8	85·7	86·7	87·7	88·7	89·7	90·7	91·7	92·7	93·7	94·6	95·6	96·6	97·6	98·6	99·5	
57·2	14	81·4	82·4	83·4	84·4	85·4	86·4	87·4	88·3	89·3	90·3	91·3	92·3	93·3	94·3	95·3	96·3	97·3	98·3	99·3	
59·0	15	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
60·8	16	80·6	81·6	82 6	83·6	84·6	85·6	86·6	87·6	88·6	89·6	90·7	91·7	92·7	93·7	94·7	95·7	96·7	97·7	98·7	99·7
62·6	17	80·2	81·2	82·2	83·2	84·2	85·2	86·2	87·2	88·2	89·3	90·3	91·3	92·4	93·4	94·4	95·4	96·4	97·4	98·5	99·5
64·4	18	79·9	80·9	81·9	82·9	83·9	84·9	85·9	86·9	87·9	88·9	89·9	91	92	93	94	95·1	96·1	97·1	98·2	99·2
66·2	19	79·5	80·5	81·6	82·6	83·6	84·6	85·6	86·6	87·6	88·6	89·6	90·7	91·7	92·7	93 7	94·8	95·8	96·9	97·9	98·9
68·0	20	79·1	80·1	81·2	82·2	83·2	84·2	85·2	86·2	87·2	88·2	89·2	90·3	91·3	92·4	93·4	94·5	95·5	96·6	97·6	98·6
69·8	21	78·7	79·7	80·8	81·8	82·8	83·8	84·8	85·9	86·9	87·9	88·9	90	91	92	93·1	94·1	95·2	96·3	97·3	98·4
71·6	22	78·4	79·4	80·4	81·4	82·4	83·4	84·4	85·5	86·5	87·6	88·6	89·6	90·7	91·8	92 8	93·9	94·9	96	97	98·1
73·4	23	78	79	80·1	81·1	82·1	83·1	84·1	85·1	86·1	87·2	88·3	89·3	90·4	91·4	92·4	93·5	94·6	95·7	96·7	97·8
75·2	24	77·6	78·6	79·7	80·7	81·7	82·7	83·7	84·7	85·7	86·8	87·9	88·9	90	91·1	92·1	93·2	94·3	95·3	96·4	97·5
77·0	25	77·3	78·3	79·3	80·3	81·3	82·3	83·4	84·4	85·4	86·5	87·5	88·6	89·7	90·7	91·8	92·9	93·9	95	96·1	97·2
78·8	26	76·9	77·9	78·9	79·9	80·9	81·9	82·9	84	85	86·1	87·2	88·2	89·3	90·4	91·5	92·5	93·6	94·7	95·8	97
80·6	27	76·5	77·5	78·5	79·5	80·5	81·6	82·6	83·6	84·7	85·7	86·8	87·9	89	90	91·1	92·2	93·3	94·4	95·5	96·7
82·4	28	76·1	77·1	78·2	79·2	80·2	81·3	82·3	83·3	84·3	85·4	86·5	87·5	88·6	89·7	90·8	91·9	93	94·1	95·2	96·4
84·2	29	75·7	76·8	77·8	78·8	79·8	80·9	81·6	83	84	85	86·1	87·2	88·2	89·3	90·4	91·6	92·7	93·8	94·9	96·1
86·0	30	75·3	76·4	77·4	78·4	79·4	80·5	81·5	82·6	83·6	84·7	85·8	86·9	87·9	89	90·1	91·2	92·4	93·5	94·6	95·8

TRALLES' and GAY-LUSSAC'S alcoholometers have been adopted in different countries; the first in Prussia, the latter in France and Sweden. They both give the per cent. of alcohol in volume. If it be desired to know the per cent. by weight, it may be ascertained from the per cent. in volume of the liquid at 60°, by the following

TABLE OF COMPARISON

Between the per cent. of alcohol by volume at 60°—TRALLES' —and per cent. by weight.

Per cent.		Per cent.	
By volume.	By weight.	By weight.	By volume.
0	0·	0	0·
5	4·00	5	6·25
10	8·05	10	12·42
15	12·15	15	18·52
20	16·28	20	24·57
25	20·46	25	30·55
30	24·69	30	36·45
35	28·99	35	42·25
40	33·39	40	47·92
45	37·90	45	53·43
50	42·52	50	58·79
55	47·29	55	63·97
60	52·20	60	68·97
65	57·25	65	73·79
70	62·51	70	78·40
75	67·93	75	82·80
80	73·59	80	86·97
85	79·50	85	90·88
90	85·75	90	94·46
95	92·46	95	97·61
100	100·00	100	100·00

Knowing the per centage volume of alcohol in a liquid at any temperature, the same results are arrived at when such per centage is multiplied by the specific gravity of the pure anhydrous spirit at the normal thermometric degree—0·7939 in TRALLES' tables, and 0·7947 in GAY-LUSSAC'S—and dividing this product by the density of the liquid at the observed temperature. Subjoined is a

TABLE BY LÖWITZ,

Giving the per cent. of absolute alcohol by weight, from the specific gravity at 68°.

Per cent. of alcohol by weight.	Specific gravity at 68°.	Per cent. of alcohol by weight.	Specific gravity at 68°.	Per cent. of alcohol by weight.	Specific gravity at 68°.	Per cent. of alcohol by weight.	Specific gravity at 68°.
100	791	74	859	48	919	23	968
99	794	73	861	47	921	22	970
98	797	72	863	46	923	21	971
97	800	71	866	45	925	20	973
96	803	70	868	44	927	19	974
95	805	69	870	43	930	18	976
94	808	68	872	42	932	17	977
93	811	67	875	41	934	16	978
92	813	66	877	40	936	15	980
91	816	65	880	39	938	14	981
90	818	64	882	38	940	13	983
89	821	63	885	37	942	12	985
88	823	62	887	36	944	11	986
87	826	61	889	35	946	10	987
86	828	60	892	34	948	9	988
85	831	59	894	33	950	8	989
84	834	58	896	32	952	7	991
83	836	57	899	31	954	6	992
82	839	56	901	30	956	5	994
81	842	55	903	29	957	4	995
80	844	54	905	28	959	3	997
79	847	53	907	27	961	2	998
78	849	52	909	26	963	1	999
77	851	51	912	25	965	0	1000
76	853	50	914	24	966		
75	856	49	917				

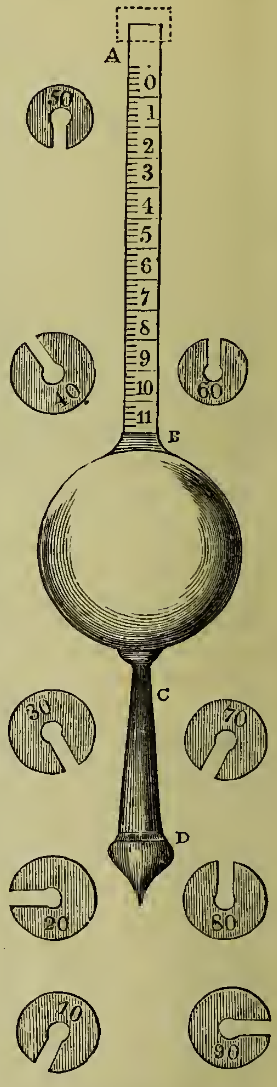
When a scale of per cent. by weight is added to TRALLES' alcoholometer, it sometimes bears the name of RICHTER'S scale, in which, as in other cases, is often meant only per cent. by weight, without reference to his original alcoholometer, and which is less accurate.

In England, the amount of revenue which flows into the Treasury annually, from the trade in spiritous liquors, renders it a matter of some importance to ascertain the real strength or per centage of alcohol with expedition and accuracy. To attain this object, various forms of alcoholometers have been constructed, some of which, as Sykes' hydrometer, have been sanctioned by the Excise board. This instrument does not at once note the specific gravity of the liquid, but the excess or deficiency of alcohol above or below a standard liquor called *proof spirit*—a term which originated in a rude method of ascertaining the strength of spirit, by pouring it upon some gunpowder in a dish, and igniting it. This was called the proof. If the gunpowder took fire at the end of the combustion, the alcoholic liquor was said to be above or over proof; but, on the other hand, if the powder did not take fire, the liquor was reputed to be below or under proof. The gunpowder test, however, is quite uncertain as to the quantity of spirit present in the liquid; for though the powder is ignited when a small portion is inflamed, yet, on employing a larger quantity, so much water is formed as to prevent the ignition. By parliamentary enactments, the strength of proof spirit has been fixed at such a density that thirteen volumes, at 51° Fahr., should equal in weight twelve volumes of water at the same temperature. According to this standard, proof spirit has a gravity of ·9186 at 60° Fahr., and contains 57·27 per cent. by volume, or 49·50 per cent. by weight, of absolute alcohol. The liquors are estimated at the quantity of spirit above or below this standard, as the case may be; and when a numeral is prefixed, it means the number of volumes that are to be added to or subtracted from a hundred volumes of the liquid, to bring it to standard or proof strength; thus, twenty-over-proof means that a hundred volumes of liquor require the addition of twenty of water to bring them to proof strength, and when a liquid is twenty-under-proof, it is understood that twenty parts of water are to be abstracted.

Sykes' hydrometer, a description of which follows, is constructed on this principle. This is selected for special illustration, partly on account of its being almost exclusively employed by the Revenue in this country, and partly from its simplicity.

It consists of a flat stem, A B—Fig. 82—3·4 inches long, which is divided on both sides into ten or sometimes eleven equal parts, and each of these subdivided into five, the scale being numbered from zero—0—to 11. The stem, A B, is soldered to a brass ball, 1·6 in. in diameter, into which is fixed a small conical stem, C D, 1·13 in. long; at the end of this is a pear-shaped loaded bulb, D, half an inch in diameter. The whole instrument is made of brass, and is 6·7 inches long. Nine circular weights accompany it, numbered 10, 20, 30, 40, *et cetera*, up to 90, and there is another weight in the form of a parallelopiped. Each of the circular weights is cut into the centre, so that they can be placed on the conical stem at C, and slid down to D; in consequence of the enlargement of the cone, they cannot slip off at D, but must be brought up to C for that purpose. The weight in the form of a parallelopiped has a square notch in one of its sides, by which it can be placed on the summit, A, of the stem. In using this instrument, it is immersed in the spirit, and pressed with the finger till sunk to zero, or 0; from the resistance felt, it will be easy to judge which weight will be required to append to it. After slipping on the weight at C, the instrument is again immersed into the liquid, and pressed with the hand till it has descended to 0 on the scale; the pressure of the hand is then withdrawn, and the apparatus is allowed to emerge and settle at the proper point of the density of the liquid, as indicated by the scale and weights. The figure on the scale to which the hydrometer sinks is now carefully observed, and the weight placed upon the conical stem added thereto; this sum, on referring to the tables which accompany the instrument, where the same number is found under the column *indication*, and to the temperature which corresponds with that of the liquid under examination, will give the per centage of alcohol. The strength is expressed in numbers, denoting the excess or deficiency per cent. of spirit in any sample. Three sliding rules, which are used instead of the tables, likewise accompany the hydrometer. The exact temperature of the liquid should be taken previous to ascertaining the gravity, as the difference in temperature, if not corrected, would give, as the result, a weaker or stronger liquor than if the thermometer stood at 60°. When Excise officers use this instrument, they are instructed to take the nearest degree above the mercury, when it stands between any two degrees of the thermometer, as also the next division below the surface of the liquid, when it marks the instrument between any two lines, thereby giving whatever advantage the difference would occasion, in favor of the trader or manufacturer. The square weight or cap shows the difference between the weight of proof spirit and that of water, as described in the first clause of the hydrometer act, being one-twelfth part of the weight of the

ig. 82.



hydrometer when loaded with the weight 60. If this weight be placed on the top of the stem at A, and the hydrometer be loaded with the weight 60, it will sink in distilled water, at the temperature of 51°, to the proof point, P, marked on the narrow edge of the stem.

The following will serve as examples to show how the strength of the spiritous liquid is ascertained:—

Example 1.—Suppose the temperature of the solution to be 47°, and that the weight, 60, is required to sink the stem of the hydrometer to 8, which, when added to the weight 60, will give 68; then, under the temperature 47°, and in a line with the marginal indication, section 60, 68 is observed, which shows that the liquor is ten and a half under proof.

Example 2.—If the stem of the instrument, when loaded with 50, sinks to 5, and the temperature, as shown by the thermometer, is 45° Fahr., then, in the marginal section headed 50, 55—equal to the weight 50, and the indication on the divided stem—is found; and under the temperature 45°, the noted strength is 10·6 per cent. over proof.

The following are two out of fifty pages in a book given with the instrument:—

40° TO 50° TEMPERATURE. WEIGHT 50.

Indication.	Temperature of the spirits by Fahrenheit's thermometer.											Indication.
	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	60°	
50	19·2	18·9	18·6	18·3	18·0	17·7	17·3	17·0	16·7	16·4	16·1	50
·2	18·9	18·6	18·3	18·0	17·7	17·4	17·0	16·7	16·4	16·1	15·8	·2
·4	18·7	18·3	18·0	17·7	17·4	17·1	16·8	16·4	16·1	15·8	15·5	·4
·6	18·4	18·1	17·8	17·5	17·2	16·9	16·5	16·2	15·9	15·6	15·3	·6
·8	18·2	17·8	17·5	17·2	16·9	16·6	16·3	15·9	15·6	15·3	15·0	·8
51	17·9	17·5	17·2	16·9	16·6	16·3	16·0	15·6	15·3	15·0	14·7	51
·2	17·6	17·2	16·9	16·6	16·3	16·0	15·7	15·3	15·0	14·7	14·4	·2
·4	17·3	16·9	16·6	16·3	16·0	15·7	15·4	15·1	14·7	14·4	14·1	·4
·6	17·1	16·7	16·4	16·1	15·8	15·5	15·2	14·8	14·5	14·2	13·9	·6
·8	16·8	16·4	16·1	15 8	15·5	15·2	14·9	14·6	14·2	13·9	13 6	·8
52	16·5	16·1	15·8	15·5	15·2	14·9	14·6	14·3	13·9	13·6	13·3	52
·2	16·2	15·8	15·5	15·2	14·9	14·6	14·3	14·0	13·6	13·3	13·0	·2
·4	15·9	15·5	15·2	14·9	14·6	14·3	14·0	13·7	13·3	13·0	12·7	·4
·6	15·6	15·3	15·0	14·7	14·4	14·1	13·7	13·4	13·1	12·8	12·5	·6
·8	15·3	15·0	14·7	14·4	14·1	13·8	13·4	13·1	12·8	12·5	12·2	·8
53	15·0	14·7	14·4	14·1	13·8	13·5	13·1	12·8	12·5	12·2	11·9	53
·2	14·7	14·4	14·1	13·8	13·5	13·2	12·8	12·5	12·2	11·9	11·6	·2
·4	14·4	14·1	13·8	13·5	13·2	12·9	12·5	12·2	11·9	11·6	11·3	·4
·6	14·2	13·9	13·6	13·3	13·0	12·7	12·3	12·0	11·7	11·4	11 1	·6
·8	13·9	13·6	13.3	13·0	12·7	12·4	12·0	11·7	11·4	11·1	10·8	·8
54	13·6	13·3	13·0	12·7	12·4	12·1	11·7	11·4	11·1	10·8	10·5	54
·2	13·3	13·0	12·7	12·4	12·1	11·8	11·4	11·1	10·8	10·5	10·2	·2
·4	13·0	12·7	12·4	12·1	11·8	11·5	11·1	10·8	10·5	10·2	9·9	·4
·6	12·8	12·5	12·2	11·8	11·5	11·2	10·9	10·6	10·2	9·9	9·6	·6
·8	12·5	12·2	11·9	11·5	11·2	10·9	10·6	10·3	9·9	9·6	9·3	·8
55	12·2	11·9	11·6	11·2	10·9	10·6	10·3	10·0	9·6	9·3	9·0	55
·2	11·9	11·6	11·3	10·9	10·6	10·3	10·0	9·7	9·3	9·0	8·7	·2
·4	11·6	11·3	11·0	10·6	10·3	10·0	9·7	9·4	9·0	8·7	8·4	·4
·6	11·3	11·0	10·7	10·4	10·1	9·7	9·4	9·1	8·8	8·5	8·1	·6
·8	11·0	10·7	10·4	10·1	9·8	9·4	9·1	8·8	8·5	8·2	7·8	·8
56	10·7	10·4	10·1	9·8	9·5	9·1	8·8	8·5	8·2	7·9	7·5	56
·2	10·4	10·1	9·8	9·5	9·2	8·8	8·5	8·2	7·9	7·6	7·2	·2
·4	10·1	9·8	9·5	9·2	8·9	8·5	8·2	7·9	7·6	7·3	6·9	·4
·6	9·9	9·6	9·3	9·0	8·6	8·3	7·9	7·6	7·3	7·0	6·7	·6
·8	9·6	9·3	9·0	8·7	8·3	8·0	7·6	7·3	7·0	6·7	6·4	·8
57	9·3	9·0	8·7	8·4	8·0	7·7	7·3	7·0	6·7	6·4	6·1	57
·2	9·0	8·7	8·4	8·1	7·7	7·4	7·0	6·7	6·4	6·1	5·8	·2
·4	8·7	8·4	8·1	7·8	7·4	7·1	6·7	6·4	6·1	5·8	5·5	·4
·6	8·4	8·1	7·8	7·5	7·2	6·8	6·5	6·1	5·8	5·5	5·2	·6
·8	8·1	7·8	7·5	7.2	6·9	6·5	6·2	5·8	5·5	5·2	4·9	·8
58	7·8	7·5	7·2	6·9	6·6	6·2	5·9	5·5	5·2	4·9	4·6	58
·2	7·5	7·2	6·9	6·6	6·3	5·9	5·6	5·2	4·9	4·6	4·3	·2
·4	7·2	6·9	6·6	6·3	6·0	5·6	5·3	4·9	4·6	4·3	4·0	·4
·6	6·9	6·6	6·3	5·9	5·7	5·3	5·0	4·7	4·3	4·0	3·7	·6
·8	6·6	6·3	6·0	5·6	5·4	5·0	4·7	4·4	4·0	3·7	3·4	·8
59	6·3	6·0	5·7	5·3	5·1	4·8	4·4	4·1	3·7	3·4	3·1	59
·2	6·0	5·7	5·4	5·0	4·8	4·4	4·1	3·8	3·4	3·1	2·8	·2
·4	5·7	5·4	5·1	4·7	4·5	4·1	3·8	3·5	3·1	2·8	2·5	·4
·6	5·4	5·1	4·8	4·4	4·1	3·8	3·5	3·2	2·8	2·5	2·1	·6
·8	5·1	4·8	4·5	4·1	3·8	3·5	3·2	2·9	2·5	2·2	1·8	·8
60	4·8	4·5	4·2	3·8	3·5	3·2	2·9	2·6	2·2	1·9	1·5	60
Indication.	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	60°	Indication.
	Temperature of the spirits by Fahrenheit's thermometer.											

WEIGHT 60. TEMPERATURE 40° TO 50°.

Indication.	Temperature of the spirit by Fahrenheit's thermometer.											Indication.
	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	
60	4·8	4·5	4·2	3·8	3·5	3·2	2·9	2·6	2·2	1·9	1·5	60
·2	4·5	4·2	3·9	3·5	3·2	2·9	2·6	2·3	1·9	1·6	1·2	·2
·4	4·2	3·9	3·6	3·2	2·9	2·6	2·3	2·0	1·6	1·3	·9	·4
·6	3·9	3·6	3·3	2·9	2·6	2·3	2·0	1·7	1·3	1·0	·6	·6
·8	3·6	3·3	3·0	2·6	2·3	2·0	1·7	1·4	1·0	·7	·3	·8
61	3·3	3·0	2·7	2·3	2·0	1·7	1·4	1·1	·7	.4	·0	61
·2	3·0	2·7	2·4	2·0	1·7	1·4	1·1	·8	·4	·1	·3	·2
·4	2·7	2·4	2·1	1·7	1·4	1·1	·8	·5	·1	·2	·6	·4
·6	2·4	2·1	1·8	1·4	1·1	·8	·4	·1	·3	·6	·9	·6
·8	2·1	1·8	1·5	1·1	·8	·5	·1	·2	·6	·9	1·2	·8
62	1·8	1·5	1·2	·8	·5	·2	·2	·5	·9	1·2	1·5	62
·2	1·5	1·2	·9	·5	·2	·1	·5	·8	1·2	1·5	1·8	·2
·4	1·2	·9	·6	·2	·1	·4	·8	1·1	1·5	1·8	2·1	·4
·6	·8	·5	·2	·2	·5	·8	1·1	1·5	1·8	2·2	2·5	·6
·8	·5	·2	·1	·5	·8	1·1	1·4	1·8	2·1	2·5	2·8	·8
63	·2	·1	·4	·8	1·1	1·4	1·7	2·1	2·4	2·8	3·1	63
·2	·1	·4	·7	1·1	1·4	1·7	2·0	2·4	2·7	3·1	3·4	·2
·4	·4	·7	1·0	1·4	1·7	2·1	2·4	2·7	3·0	3·4	3·7	·4
·6	·8	1·1	1·4	1·8	2·1	2·4	2·7	3·1	3·4	3·8	4·1	·6
·8	1·1	1·4	1·7	2·1	2·4	2·8	3·1	3·4	3·7	4·1	4·4	·8
64	1·4	1·7	2·0	2·4	2·7	3·1	3·4	3·7	4·0	4·4	4·1	64
·2	1·7	2·0	2·3	2·7	3·0	3·4	3·7	4·0	4·3	4·7	5·6	·2
·4	2·0	2·3	2·6	3·0	3·3	3·7	4·1	4·4	4·7	5·1	5·4	·4
·6	2·4	2·7	3·0	3·4	3·7	4·1	4·4	4·7	5·0	5·4	5·7	·6
·8	2·7	3·0	3·3	3·7	4·0	4·4	4·8	5·1	5·4	5·8	6·1	·8
65	3·0	3·3	3·6	4·0	4·3	4·7	5·1	5·4	5·7	6·1	6·4	65
·2	3·3	3·6	3·9	4·3	4·6	5·0	5·4	5·7	6·0	6·4	6·7	·2
·4	3·6	4·0	4·3	4·7	5·0	5·4	5·7	6·1	6·4	6·8	7·1	·4
·6	4·0	4·3	4·6	5·0	5·3	5·7	6·1	6·4	6·7	7·1	7·4	·6
·8	4·3	4·7	5·0	5·4	5·7	6·1	6·4	6·8	7·1	7·5	7·8	·8
66	4·6	5·0	5·3	5·7	6·0	6·4	6·7	7·1	7·4	7·8	8·1	66
·2	5·0	5·3	5·7	6·0	6·3	6·7	7·0	7·4	7·7	8·1	8·4	·2
·4	5·3	5·7	6·0	6·4	6·7	7·1	7·4	7·8	8·1	8·5	8·8	·4
·6	5·7	6·0	6·4	6·7	7·0	7·4	7·7	8·1	8·4	8·8	9·1	·6
·8	6·0	6·4	6·7	7·1	7·4	7·8	8·1	8·5	8·8	9·2	9·5	·8
67	6·4	6·7	7·1	7·4	7·7	8·1	8·4	8·8	9·1	9·5	9·8	67
·2	6·7	7·0	7·4	7·7	8·0	8·4	8·7	9·1	9·4	9·8	10·1	·2
·4	7·1	7·4	7·8	8·1	8·4	8·8	9·1	9·5	9·8	10·2	10·5	·4
·6	7·4	7·7	8·1	8·4	8·7	9·1	9·4	9·8	10·1	10·5	10·8	·6
·8	7·8	8·1	8·5	8·8	9·1	9·5	9·8	10·2	10·5	10·9	11·2	·8
68	8·1	8·4	8·8	9·1	9·4	9·8	10·1	10·5	10·8	11·2	11·5	68
·2	8·5	8·8	9·1	9·4	9·8	10·2	10·5	10·9	11·2	11·6	11·9	·2
·4	8·8	9·1	9·5	9·8	10·1	10·5	10·8	11·2	11·5	11·9	12·2	·4
·6	9·2	9·5	9·8	10·1	10·5	10·9	11·2	11·6	11·9	12·3	12·6	·6
·8	9·5	9·8	10·2	10·5	10·8	11·2	11·5	11·9	12·2	12·6	12·9	·8
69	9·9	10·2	10·5	10·8	11·2	11·6	11·9	12·3	12·6	13·0	13·3	69
·2	10·3	10·6	10·9	11·2	11·6	12·0	12·3	12·7	13·0	13·4	13·7	·2
·4	10·6	10·9	11·2	11·5	11·9	12·3	12·6	13·0	13·3	13·7	14·0	·4
·6	11·0	11·3	11·6	11·9	12·3	12·7	13·0	13·4	13·7	14·1	14·4	·6
·8	11·3	11·6	11·9	12·2	12·6	13·0	13·3	13·7	14·0	14·4	14.7	·8
70	11·7	12·0	12·3	12·6	13·0	13·4	13·7	14·1	14·4	14·8	15·1	70
Indication.	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	Indication.
	Temperature of the spirit by Fahrenheit's thermometer.											

A modification of Sykes' hydrometer has been recently adapted for the testing of alcoholic liquors. It is constructed of glass, and is in the shape of an ordinary hydrometer, the stem being divided into degrees from 1 to 100: it carries a small delicate spirit thermometer in the bulb, to which a scale is affixed, having references from 0° to 12°, corresponding to FAHRENHEIT'S scale from 32° to 80°. The temperature of the menstrua is indicated by the small thermometer; and the calculations in the tables accompanying the instrument are made to accord with these numbers. There are tables supplied with the hydrometer, which are headed by the degrees and half degrees of the thermometric scale; and the corresponding content of spirit over or under proof at the respective degree of the table is placed opposite each degree of the hydrometer.

When the instrument is used to ascertain the value of a liquid, the degree of immersion, and also that of the thermometer are noted; on referring to the table headed by the observed temperature, the per centage of spirit over or under proof is found opposite the degree to which the hydrometer sunk in the liquid.

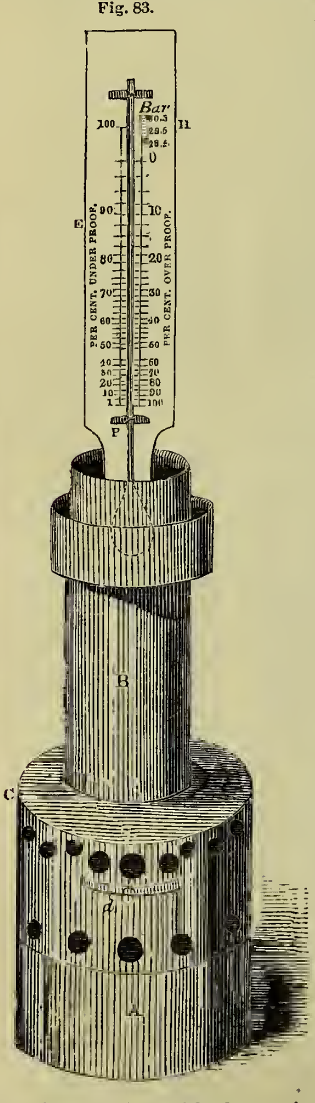
By SYKES' hydrometer, the specific gravity of the spirit indicating proof strength is ·9200. URE has constructed a table, appended below, wherein the specific gravity corresponds to the strength noted by the hydrometer, whether over or under proof strength.

CORRESPONDENCE BETWEEN THE SPECIFIC GRAVITIES AND PER CENTS. OF ALCOHOL OVER PROOF AT 60° FAHRENHEIT.

Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. over proof.	Specific gravity.	Per cent. under proof.	Specific gravity.	Per cent. under proof.
0·8156	67·0	0·8410	54·2	0·8657	39·3	0·8912	21·9	0·9178	1·9	0·9445	21·9	0·9722	58·3
8160	66·8	8413	54·1	8660	39·1	8915	21·7	9182	1·6	9448	22·2	9726	59·0
8163	66·6	8417	53·9	8664	38·9	8919	21·4	9185	1·3	9452	22·7	9730	59·7
8167	66·5	8420	53·7	8667	38·7	8922	21·2	9189	1·0	9456	23·1	9734	60·4
8170	66·3	8424	53·5	8671	38·4	8926	20·9	9192	0·7	9460	23·5	9738	61·1
8174	66·1	8427	53·3	8674	38·2	8930	20·6	9196	0·3	9464	23·9	9742	61·8
8178	65·6	8431	53·1	8678	38·0	8933	20·4	9200	Proof.	9468	24·3	9746	62·5
8181	65·8	8434	52·9	8681	37·8	8937	20·1	Under proof.		9472	24·7	9750	63·2
8185	65·6	8438	52·7	8685	37·6	8940	19·9	9204	0·3	9476	25·1	9754	63·9
8188	65·5	8441	52·5	8688	37·3	8944	19·6	9207	0 6	9480	25·5	9758	64·6
8192	65·3	8445	52·3	8692	37·1	8948	19·3	9210	0·9	9484	25·9	9762	65·3
8196	65·1	8448	52·1	8695	36·9	8951	19·1	9214	1·3	9488	26·3	9766	66·0
8199	65·0	8452	51·9	8699	36·7	8955	18·8	9218	1 6	9492	26·7	9770	66·7
8203	64·8	8455	51·7	8702	36·4	8959	18·6	9222	1·9	9496	27·1	9774	67·4
8206	64·7	8459	51·5	8706	36·2	8962	18·3	9226	2·2	9499	27·5	9778	68·0
8210	64·5	8462	51·3	8709	35·9	8966	18·0	9229	2·5	9503	28·0	9782	68·7
8214	64·3	8465	51·1	8713	35·7	8970	17·7	9233	2·8	9507	28·4	9786	69·4
8218	64·1	8469	50·9	8716	35·5	8974	17·5	9237	3·1	9511	28·8	9790	70·1
8221	64·0	8472	50·7	8720	35·2	8977	17·2	9241	3·4	9515	29·2	9794	70·8
8224	63·8	8476	50·5	8723	35·0	8981	16·9	9244	3·7	9519	29·7	9798	71·4
8227	63·6	8480	50·3	8727	34·7	8985	16·6	9248	4·0	9522	30·1	9802	72·1
8231	63·4	8482	50·1	8730	34·5	8989	16·4	9252	4·4	9526	30·6	9806	72·8
8234	63·2	8486	49·9	8734	34·3	8992	16·1	9255	4·7	9530	31·0	9810	73·5
8238	63·1	8490	49·7	8737	34·1	8996	15·9	9259	5·0	9534	31·4	9814	74·1
8242	62.9	8493	49·5	8741	33·8	9000	15·6	9263	5·3	9539	31·1	9818	74·8
8245	62·7	8496	49·3	8744	33·6	9004	15·3	9267	5·7	9542	32·3	9822	75·4
8249	62·5	8499	49·1	8748	33·4	9008	15·0	9270	6·0	9546	32·8	9826	76·1
8252	62·3	8503	48·9	8751	33·2	9011	14·8	9274	6·4	9550	33·2	9830	76·7
8256	62·2	8506	48·7	8755	32·9	9015	14·5	9278	6·7	9553	33·7	9834	77·3
8259	62·0	8510	48·5	8758	32·7	9019	14·2	9282	7·0	9557	34·2	9838	78·0
8263	61·8	8513	48.3	8762	32·4	9023	13·9	9286	7·3	9561	34·7	9842	78·6
8266	61·6	8516	48·0	8765	32·2	9026	13·6	9291	7·7	9565	35·1	9846	79·2
8270	61·4	8520	47·8	8769	32·0	9030	13·4	9295	8·0	9569	35·6	9850	79·8
8273	61·3	8523	47·6	8772	31·7	9034	13·1	9299	8·3	9573	36·1	9854	80·4
8277	61·1	8527	47·4	8776	31·5	9038	12·8	9302	8·6	9577	36·6	9858	81·1
8280	60·9	8530	47·2	8779	31·2	9041	12·5	9306	9·0	9580	37·1	9862	81·7
8284	60·7	8533	47·0	8783	31·0	9045	12·2	9310	9·3	9584	37·6	9866	82·3
8287	60·5	8537	46·8	8786	30·8	9049	12·0	9314	9·7	9588	38·1	9870	82·9
8291	60·4	8540	46·6	8790	30·5	9052	11·7	9318	10·0	9592	38·6	9874	83·5
8294	60·2	8543	46·4	8793	30·3	9056	11·4	9322	10·3	9596	39·1	9878	84·0
8298	60·0	8547	46·2	8797	30·0	9060	11·1	9326	10·7	9599	39·6	9882	84·6
8301	59·8	8550	46·0	8800	29·8	9064	10·8	9329	11·0	9603	40·1	9886	85·2
8305	59·6	8553	45·8	8804	29·5	9067	10·6	9332	11·4	9607	40·6	9890	85·8
8308	59·5	8556	45·6	8807	29·3	9071	10·3	9337	11·7	9611	41·1	9894	86·3
8312	59·3	8560	45·4	8811	29·0	9075	10·0	9341	12·1	9615	41·7	9898	86·9
8315	59·1	8563	45·2	8814	28·8	9079	9·7	9345	12·4	9619	42·2	9902	87·4
8319	58·9	8566	45·0	8818	28·5	9082	9·4	9349	12·8	9623	42·8	9906	88·0
8322	58·7	8570	44·8	8822	28·3	9085	9·2	9353	13·1	9627	43·3	9910	88·5
8326	58·6	8573	44·6	8825	28·0	9089	8·9	9357	13·5	9631	43·9	9914	89·1
8329	58·4	8577	44·4	8829	27·8	9093	8·6	9360	13·9	9635	44·4	9918	89·6
8333	58·2	8581	44·2	8832	27·5	9097	8·3	9364	14·2	9638	45·0	9922	90·2
8336	58·0	8583	43·9	8836	27·3	9100	8·0	9368	14·6	9642	45·5	9926	90·7
8340	57·8	8587	43·7	8840	27·0	9104	7·7	9372	14·9	9646	46·1	9930	91·2
8344	57·7	8590	43·5	8843	26·8	9107	7·4	9376	15·3	9650	46·7	9934	91·7
8347	57·5	8594	43·3	8847	26·5	9111	7·1	9380	15·7	9654	47·3	9938	92·3
8351	57·3	8597	43·1	8850	26·3	9115	6·8	9384	16·0	9657	47·9	9942	92·8
8354	57·1	8601	42·8	8854	26·0	9118	6·5	9388	16·4	9661	48·5	9946	93·3
8358	56·9	8604	42·6	8858	25·8	9122	6·2	9392	16·7	9665	49·1	9950	93·8
8362	56·8	8608	42·4	8861	25·5	9126	5·9	9396	17·1	9669	49·7	9954	94·3
8365	56·6	8611	42·2	8865	25·3	9130	5·6	9399	17·5	9674	50·3	9958	94·9
8369	56·4	8615	42·0	8869	25·0	9134	5·3	9403	17·8	9677	51·0	9962	95·4
8372	56·2	8618	41·7	8872	24·8	9137	5·0	9407	18·2	9681	51·6	9966	95·9
8376	56·0	8622	41·5	8876	24·5	9141	4·8	9411	18·5	9685	52·2	9970	96·4
8379	55·9	8625	41·3	8879	24·3	9145	4·5	9415	18·9	9689	52·9	9974	96·8
8383	55·7	8629	41·1	8883	24·0	9148	4·2	9419	19·3	9693	53·3	9978	97·3
8386	55·5	8632	40·9	8886	23·8	9152	3·9	9422	19·7	9697	54·2	9982	97·7
8390	55·3	8636	40·6	8890	23·5	9156	3·6	9426	20·0	9701	54·8	9986	98·2
8393	55·1	8639	40·4	8894	23·2	9159	3·3	9430	20·4	9705	55·5	9990	98·7
8396	55·0	8643	40·2	8897	23·0	9163	3·0	9434	20·8	9709	56·2	9993	99·1
8400	54·8	8646	40·0	8901	22·7	9167	2·7	9437	21·2	9713	56·9	9997	99·6
8403	54·6	8650	39·8	8904	22·5	9170	2·4	9441	21·6	9718	57·6	1·0000	100·0
8407	54·4	8653	39·6	8908	22·2	9174	2·1						

Although it had long been known that the boiling point of water was raised by holding in solution neutral salts and other bodies, and although many experiments were instituted with the view of ascertaining the proportion of salts or sugar present in liquids, still the application of this fact to the determination of the quantity of alcohol in spiritous liquors was reserved for the Abbé Brossard-Vidal, of Toulon, who ascertained that the boiling point of such liquors was in direct proportion to the quantity of alcohol they contained, irrespective of any amount of saline ingredients present in them. When certain salts are added to dilute alcohol, such as carbonate of potassa or chloride of calcium, which are capable of abstracting a portion of the water, the boiling point of the solution is lowered, instead of the reverse being the case. On these principles the Abbé constructed his apparatus, whereby the Revenue Boards of France might furnish themselves with ready proof if the wines entered were genuine, as it was frequently found that brandy had been passed under the name of wine, and a fraud thus committed, the duty on alcoholic and strong spiritous liquors being much greater than on wine.

Fig. 83.



These principles also formed the basis of Mr. Field's alcoholometer for the determination of the quantity of spirit in liquors, and for which he obtained a patent in 1847. It consisted originally of a spirit lamp, surmounted by a boiler containing the liquid to be examined, and a large cylindrical glass bulb containing mercury, and having an upright stem, whose calibre was such as to allow the expansion of the mercury to elevate a small glass float which rested on its surface. This float was connected by a thread with a similar bead, which hung in the open air; the thread passed over a pulley which, turning with the motion of the beads, caused the index to move along the circular graduated scale. This instrument was much improved by Dr. Ure, who introduced, instead of the cylindrical bulb and beads, a thermometer attached to a graduated scale. Fig. 83 shows the improved instrument.

A is the spirit lamp, surrounded by an outer coating containing cold water for keeping the lamp cool, should many experiments be required to be made in succession; B the boiler, which fits into the cage, C, in the case of the lamp; a damper, *d*, modifies or extinguishes the heat of the lamp when required; E is the thermometer with a very small bore, after the manner of Wollaston's instrument for determining the height of mountains by the boiling point of water on their summit. The bottom of the scale on the ebullition thermometer is marked P, for proof, on the left side, and 100—proof spirit—on the right side. It corresponds with 178·6 Fahr., nearly, or the boiling point of alcohol, spec. grav. ·920.

From the mean of a great number of experiments, Ure drew up the following table, which shows the boiling point of alcohol of various specific gravities:—

Temperature Fahr.	Specific gravity.		
178·5	0·9200	—	Proof.
179·75	0·9321	10	Under proof.
180·4	0·9420	20	"
182·01	0·9516	30	"
183·40	0·960	40	"
185·6	0·9665	50	"
189·0	0·9729	60	"
191·8	0·9786	70	"
196·4	0·9850	80	"
202·0	0·992	90	"

When spirit is over proof, the variation of the boiling point is so small that a strictly accurate result cannot conveniently be obtained, and, in fact, proof spirit, or spirit approaching to that strength, is more accurately tested by diluting it with its own bulk of water, before ascertaining the strength, and then doubling the result. Another source of error pointed out by Ure, is the elevation of the boiling point, when the liquor is kept heated for any length of time; it is, however, nearly obviated by the addition of common salt to the solution in the boiler of the apparatus, in the proportion of thirty-five or forty grains. This substance has the curious property of arresting the mercury in the thermometer at the boiling point of the wine, spirit, or beer, submitted to examination, and thus offers a means by which a proper reading can be made. In order to correct the difference arising from a higher or lower pressure of the atmosphere, distilled water should be boiled in the apparatus, and the temperature noted; for the boiling point of the alcoholic solutions will vary as that of the water, when the pressure of the atmosphere is greater or less. In order to correct this source of error, a subsidiary barometrical scale, II, is attached to the thermometer, E. The method of using the alcoholometer is as follows:—

The lamp, A, is lighted; B is filled to about one inch from the top with the liquid to be examined, to which a paper of common salt is added, and the whole is then placed on the lamp, A; and lastly, the thermometer, E, is fixed to the scale, with its bulb immersed in the liquid. Before commencing general operations for the day, the boiler, B, is filled with water, and boiled; if the column of mercury remains at 29·5, which is placed opposite to 100 on the scale at the left hand—the mean boiling point of water—no correction is required to be made; but if it stands higher or lower than this figure, the various boiling points of the samples bear reference to this. In testing the solutions, when the mercury begins to rise out of the bulb of the thermometer, the damper is to be pushed in midway into the groove to lower the heat. As the liquid boils freely, the mercury in the tube will become stationary, and the figure on the left indicates the per centage under proof, while that on the right shows the per centage over proof. Field's alcoholometer only tells the quantity of alcohol, but an auxiliary experiment with the hydrometer will readily give the specific gravity, and upon reference to Table I., the amount of saccharine and extractive matter is ascertained. In testing wines, the specific gravity of the liquid is first taken, then the boiling point ascertained by the alcoholometer, and the corresponding specific gravity deducted from that previously found by the hydrometer; the difference will, upon referring to Table II., show the quantity of extractive and saccharine matter in a hundred gallons of the liquid. For example, if the specific gravity by the hydrometer be ·989, and that by the alcoholometer shows the presence of alcohol of sixty-nine and six-tenths, whose specific gravity is ·979 by the tables, deduct the latter gravity from the gravity of the bulk, or ·989, and a difference of ten remains, which number, upon reference to Table II., will give twenty-five pounds of saccharine and extractive matter in a hundred gallons, combined with thirty gallons and four-tenths of proof spirit. Should the barometer of the day mark any other indication above or below the standard 29·5, the thermometer scale will then only show the apparent strength, and reference must be had to the small ivory indicator, it being the counterpart of the barometrical scale of the thermometer; thus, if the barometer indicate 30, place 30 of the indicator against the boiling point of the liquid, and opposite the line of 29·5 will be found the true strength.

Example 1.—Barometer at 30.—Suppose the mercury to stop at the same point, 72 u.p.; place 30 of the indicator against 72 on the thermometer, and the line 28·5 will cut 69·6 u.p., the true per centage.

Example 2.—Barometer at 29.—Suppose the mercury to stop at the same point, 72 u.p.; place 29 of the indicator against 72 on the thermometer, and the line 29·5 will cut 74·3 u.p., the true strength.

To ascertain the strength of malt liquors and their respective values, the instrument has been furnished with a glass saccharometer, testing glass, and slide rule. Commence by charging the test glass with the liquid, then insert the saccharometer to ascertain the present gravity or density per barrel, and at whatever number it floats, that will indicate the number of pounds per barrel the liquor is heavier than water:—

Example 1.—Suppose the saccharometer to float at the figure 8, which would indicate eight pounds per barrel; then submit the liquid to the boiling test, with an addition of salt to arrest the mercury at the proper boiling point of the liquid, as before mentioned; now, suppose it should show—the barometrical difference being accounted for—90 u.p., that would be equivalent to ten per cent. of proof alcohol. Refer to the slide scale, and place A on the slide against 10 on the upper line of figures, and facing B on the lower line will be 18, showing that eighteen pounds per barrel have been decomposed to constitute that per centage of spirit; then, by adding eighteen pounds to the present eight pounds per barrel, the result will be twenty-six pounds, the original weight of the wort after leaving the copper.

Example 2.—The saccharometer marks ten pounds per barrel, and at the boiling point it indicates 88 u.p., equivalent to 12 gallons of proof spirit per cent.; place A against 12, and opposite B will be 21½, the number of pounds per barrel, which, when added to the ten pounds present, will give a total of thirty-one and a half pounds.

To ascertain the relative value.—Suppose the price of the twenty-six pounds beer to be thirty-six shillings per barrel, and the thirty-one pounds beer to be forty shillings—to ascertain which beer will be the cheaper, place 26 on the opposite side of the rule against 36, and opposite 31½ pounds will be forty-three shillings and seven pence, showing that the latter beer is cheaper by three shillings and seven pence per barrel. By this instrument the quantity of spirit per cent. in distiller's wort, whether it be in progress of fermentation or ready for the still, is indicated, the only difference being in the allowances in the sliding rule. Saccharometers applicable to the foregoing rules for beer, ale, *et cetera*, have been adjusted at the temperature of 60° Fahr., and will be found correct for general purposes; but where extreme minuteness is required, the variation of temperature must be taken into account, and for every ten degrees of temperature above 60°, three-tenths of a pound must be added to the gross amount found by the slide rule; on the contrary, for every ten degrees below 60°, three-tenths of a pound must be deducted.

For Cordialized Spirits.—The operation in this instance is different from that applied to the testing of beers, which have the alcohol generated in the worts; for in cordialized spirits of every kind, the alcohol is the original, and the saccharine matter, or sugar, is an addendum. If a hundred gallons of spirit are required of a given strength—say fifty per cent. under proof—fifty gallons of proof spirit to which fifty gallons of water are added, will be of this strength, and upon testing it by the alcoholometer, it will be found as correct as by the hydrometer. But in cordializing spirit, the reverse is the case; for to the fifty gallons of spirit, proof strength, fifty gallons of sugar and water would be added, thereby rendering the hydrometer useless, excepting for taking the specific gravity of the bulk, and, according to the quantity of sugar present, so a relative quantity of water must have been displaced; and as the sugar has no reducing properties, the alcoholometer will only show the strength of the cordial in relation to the quantity of water contained in it, as the principle indicates, irrespective of the saccharine or extractive matter. Suppose, in making one hundred gallons of cordial at 50 u.p., three pounds of sugar are put to the gallon, or three hundred pounds to the hundred gallons, these three hundred pounds displacing 18·67 gallons of water, only 31·33 gallons of the water, instead of fifty, have been applied; the sugar, without reducing properties, making up the bulk of one hundred gallons, which is meant to represent fifty per cent. u.p.

The alcoholometer will only show at the full point of ebullition the alcoholic strength in relation to the water in one hundred gallons of the mixture, or thirty-five per cent. U.P., leaving fifteen per cent. to be accounted for in the bulk. As the quantity of sugar present must be determined before that per centage can be arrived at, a double object will be effected by so doing, namely, eliciting in all instances the quantity of sugar present, as well as the per centage of spirit to be accounted for; as an example, suppose the specific gravity of a cordial is 1·076, then submit the liquid to the boiling point, and having ascertained the per centage of alcohol—thirty-five U.P.—the specific gravity of alcohol at that strength will be found to be 0·956; deduct 0·956 from the specific gravity of the bulk, or 1·076, and ·120 will remain; refer that to its amount in the head line of Table II., namely, 120, under which will be found 3, representing three pounds of sugar to the gallon; and by running the eye down its column to opposite the alcoholic strength indicated—thirty-five U.P.—will be found 14·9, representing the water displaced by the sugar, and which amount added to 35 per cent. ascertained, makes the total upon the bulk 49·9 per cent. U.P., with three pounds of sugar to the gallon.

TABLE I.

Table of specific gravities by Sykes' hydrometer, adapted to Field's patent alcoholometer for cordialized spirits.

Temperature, 60°.—Specific gravity of water, 1·000°.

60		70		80		90		100		110		120		130		140		150		160		170		180	
Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.
60	922	70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175
1	924	1	943	1	963	1	983	1	1002	1	1022	1	1044	1	1065	1	1087	1	1109	1	1131	1	1155	1	1178
2	926	2	945	2	965	2	985	2	1004	2	1024	2	1046	2	1067	2	1089	2	1111	2	1134	2	1157	2	1180
3	928	3	947	3	967	3	987	3	1006	3	1026	3	1048	3	1069	3	1091	3	1113	3	1136	3	1159	3	1182
4	930	4	949	4	969	4	989	4	1008	4	1029	4	1050	4	1071	4	1093	4	1116	4	1139	4	1162	4	1185
5	932	5	951	5	971	5	991	5	1010	5	1031	5	1052	5	1074	5	1096	5	1118	5	1141	5	1164	5	1187
6	934	6	953	6	973	6	993	6	1012	6	1033	6	1054	6	1076	6	1098	6	1120	6	1143	6	1166	6	1189
7	936	7	955	7	975	7	995	7	1014	7	1035	7	1056	7	1078	7	1100	7	1123	7	1145	7	1168	7	1191
8	938	8	957	8	977	8	997	8	1016	8	1037	8	1058	8	1080	8	1102	8	1125	8	1148	8	1171	8	1194
9	940	9	959	9	979	9	999	9	1018	9	1039	9	1061	9	1082	9	1104	9	1127	9	1150	9	1173	9	1196
70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175	190	1199

TABLE II.

Table showing the lbs. of sugar per gallon in cordialized spirits, with the per centages to be added to the indicated strength, per the alcoholometer.

Difference of gravity. Lbs. of sugar per gallon.		10 4 oz. or 25 to 100.	15 6 oz. 37½ to 100.	20 8 oz. 50 to 100.	25 10 oz. 62½ to 100.	30 12 oz. 75 to 100.	35 14 oz. 87½ to 100.	40 1·0	45 oz. 1·2	50 oz. 1·4	Difference of gravity. Lbs. of sugar per gallon.	
Sp. grav. of spirit.	Per cent. of spirit.										Per cent. of spirit.	Sp. grav. of spirit.
920	Proof.	1·6	2·5	3·4	4·4	5·3	6·2	7·1	8·1	9·0	Proof.	920
923	2·5	1·6	2·5	3·3	4·3	5·2	6·1	6·9	7·8	8·8	2·5	923
926	5·	1·5	2·4	3·2	4·2	5·0	5·9	6·8	7·7	8·6	5·	926
929	7·5	1·5	2·3	3·2	4·1	4·9	5·8	6·6	7·5	8·4	7·5	929
932	10·	1·4	2·2	3·1	4·0	4·8	5·7	6·5	7·4	8·2	10·	932
935	12·5	1·4	2·2	3·1	3·9	4·7	5·5	6·3	7·2	8·0	12·5	935
938	15·	1·4	2·1	3·0	3·8	4·6	5·4	6·2	7·0	7·8	15·	938
940	17·5	1·3	2·1	2·9	3·7	4·5	5·3	6·0	6·8	7·6	17·5	940
943	20·	1·3	2·0	2·8	3·6	4·4	5·2	5·9	6·7	7·5	20·	943
945	22·5	1·3	2·0	2·7	3·5	4·3	5·0	5·7	6·5	7·3	22·5	945
948	25·	1·2	1·9	2·6	3·4	4·1	4·8	5·5	6·3	7·0	25·	948
950	27·5	1·2	1·9	2·5	3·3	4·0	4·7	5·3	6·1	6·8	27·5	950
952	30·	1·1	1·8	2·4	3·1	3·8	4·5	5·1	5·8	6·5	30·	952
954	32·5	1·1	1·7	2·3	3·0	3·6	4·3	4·8	5·5	6·2	32·5	954
956	35·	1·0	1·6	2·2	2·9	3·5	4·1	4·6	5·3	6·0	35·	956
958	37·5	1·0	1·6	2·1	2·8	3·4	3·9	4·4	5·1	5·8	37·5	958
960	40·	·9	1·5	2·0	2·7	3·2	3·8	4·3	4·9	5·5	40·	960
962	42·5	·9	1·5	2·0	2·6	3·1	3·6	4·1	4·7	5·3	42·5	962
964	45·	·9	1·4	1·9	2·5	3·0	3·5	4·0	4·6	5·1	45·	964
965	47·5	·8	1·4	1·9	2·4	2·9	3·4	3·9	4·4	4·9	47·5	965
967	50·	·8	1·3	1·8	2·3	2·8	3·3	3·8	4·3	4·8	50·	967
969	52·5	·7	1·2	1·7	2·2	2·6	3·1	3·6	4·1	4·5	52·5	969
970	55·	·7	1·2	1·6	2·0	2·4	2·9	3·4	3·8	4·2	55·	970
972	57·5	·6	1·1	1·5	1·9	2·2	2·7	3·1	3·5	3·9	57·5	972
973	60·	·6	1·0	1·4	1·8	2·1	2·5	2·9	3·3	3·6	60·	973
974	62·5	·6	1·0	1·3	1·7	2·0	2·4	2·7	3·1	3·5	62·5	974
976	65·	·5	·9	1·2	1·5	1·8	2·2	2·5	2·8	3·1	65·	976
977	67·5	·5	·8	1·1	1·4	1·7	2·0	2·3	2·6	2·9	67·5	977
979	70·	·4	·7	1·0	1·3	1·5	1·8	2·1	2·4	2·6	70·	979
980	72·5	·4	·7	·9	1·1	1·3	1·6	1·9	2·1	2·3	72·5	980
982	75·	·3	·6	·8	1·0	1·2	1·4	1·6	1·8	2·0	75·	982
983	77·5	·3	·5	·7	·9	1·0	1·2	1·4	1·6	1·8	77·5	983
984	80·	·2	·4	·6	·8	·9	1·0	1·2	1·4	1·6	80·	984
986	82·5	·2	·3	·5	·7	·8	·9	1·0	1·2	1·4	82·5	986
988	85·	·2	·2	·4	·6	·7	·8	·9	1·0	1·2	85·	988
990	87·5	·1	·2	·3	·5	·6	·7	·8	·9	1·0	87·5	990
992	90·	·1	·1	·2	·4	·5	·6	·7	·8	·9	90·	992
994	92·5	..	·1	·2	·3	·4	·5	·6	·7	·8	92·5	994
996	95·	..	..	·1	·2	·3	·4	·5	·6	·7	95·	996
998	97·5	..	..	..	·1	·2	·3	·4	·5	·6	97·5	998

Table I., which shows the specific gravity on the bulk of the mixture, bears reference to the table following it —Table II. of the alcoholometer.

In estimating the density of various gins and cordials, suppose the specific gravity of the liquid is found to be ·957, and by the boiling point it proves to be 14 U.P., whose specific gravity is ·937; when this is deducted from the former—·957—the remainder is 20, under which, in Table II. will be found ½, or one-half pound of sugar to the gallon; and, on observing the opposite 14 U.P., 3·0 will be found, which, added to 14, makes the total on the bulk 17 per cent. U.P., with fifty pounds of sugar to the hundred gallons.

Care must be taken that the mercury is entirely in the bulb of the thermometer before it is fixed to the stem for operation; and the salt must be added in all cases when determining the boiling point, except for water.

The instrument is highly advantageous by proving the relative quantity of fruit or *saccharum*, and alcohol, requisite to constitute the normal wine of each species.

Some beers possess the remarkable power of causing drowsiness and stupor, without a corresponding previous exhilaration, and on this account may be justly suspected of having been sophisticated with *cocculus indicus*, opium, or some analogous drug; and this suspicion may become certainty if they be shown by the alcoholometer to contain only a few per cent. of fermented spirit.—*Ure.*

Fownes's paper on the value, in absolute alcohol, of spirits of different specific gravities, is ingenious and valuable; the leading features of it are therefore quoted.

The table was formed synthetically; absolute alcohol and distilled water were weighed out in the required proportions, mixed in small closely-stopped bottles, and well shaken together. After standing three or four days, the mixtures were brought to the temperature of 60° Fahr. exactly, and their specific gravities determined with great care. When two or three days more had elapsed, this last-named operation was repeated, but in no case was it observed that any further contraction had occurred. Neither was the specific gravity of a mixture, containing nearly equal parts alcohol and water, which had been so examined, changed by being enclosed in a strong accurately-stoppered bottle, and heated for some time to a temperature above its boiling point.

In this manner, every alternate number in the table —every even number—was obtained by direct experiment; the others were then incorporated. When completed, the table was examined by various methods calculated to test its accuracy, but no error of sufficient magnitude to limit its usefulness was detected.

The absolute alcohol employed in these experiments, was prepared in the following manner:—The strongest rectified spirit was agitated with half its weight of carbonate of potassa, deprived of water of crystallization, and left in contact with it for some days. It was then decanted upon half its weight of powdered quicklime, made from black marble, contained in a metal still, which could be perfectly closed. The mixture of spirit and lime was retained in a warm situation for a week or thereabouts, and then distilled by means of a water-bath. By this treatment the specific gravity of the alcohol was reduced to 0·796, or even below, and by a repetition of the process of digestion with powdered lime, and redistillation, the last traces of water were removed. In this manner, without difficulty, the very considerable quantity of absolute alcohol required for the experiments was procured. Absolute alcohol thus obtained, has the specific gravity ·7938 at 60° Fahr.; it is extremely expansible by heat, which renders the determination of its exact specific gravity difficult and troublesome when the temperature of the room is either above or below 60°. The same remark applies to the mixtures of alcohol and water extending over more than half the table, the most minute precautions regarding temperature being necessary to avoid serious errors. In a glass retort containing pieces of copper foil, absolute alcohol boils at 177° Fahr., the barometer standing at 29·75 inches. Lastly, when analyzed by combustion with oxide of copper, it yields numbers representing the proportion of carbon and hydrogen present, so closely agreeing with those required by theory as to leave no doubt of its purity and freedom from all admixture.

TABLE OF THE PROPORTION BY WEIGHT

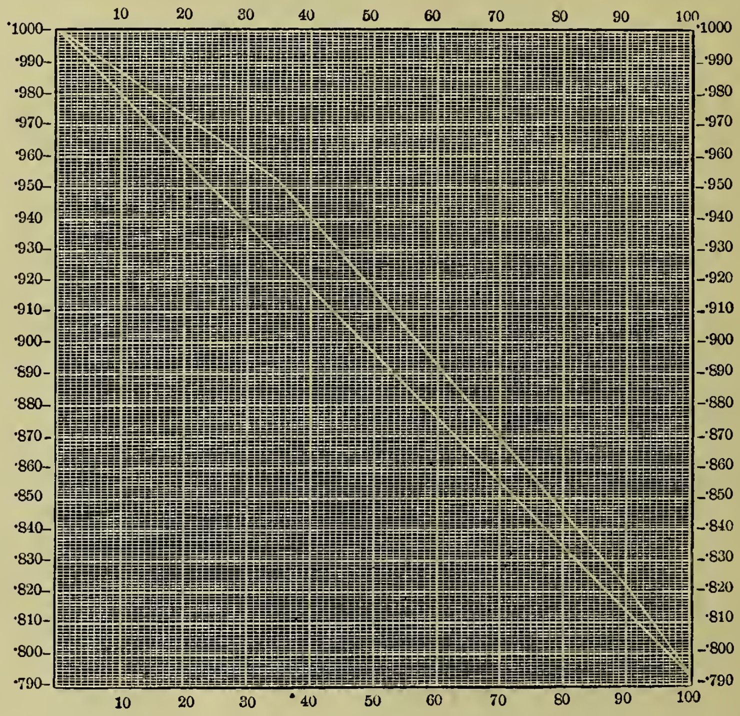
Of real or absolute alcohol contained in 100 parts of spirits of different specific gravities, at the temperature of 60° Fahr.

Specific gravity.	Per centage of alcohol.	Specific gravity.	Per centage of alcohol.	Specific gravity.	Per centage of alcohol.
·9991	0·5	·9511	34	·8769	68
·9981	1	·9490	35	·8745	69
·9965	2	·9470	36	·8721	70
·9947	3	·9452	37	·8696	71
·9930	4	·9434	38	·8672	72
·9914	5	·9416	39	·8649	73
·9898	6	·9396	40	·8625	74
·9884	7	·9376	41	·8603	75
·9869	8	·9356	42	·8581	76
·9855	9	·9335	43	·8557	77
·9841	10	·9314	44	·8533	78
·9828	11	·9292	45	·8508	79
·9815	12	·9270	46	·8483	80
·9802	13	·9249	47	·8459	81
·9789	14	·9228	48	·8434	82
·9778	15	·9206	49	·8408	83
·9766	16	·9184	50	·8382	84
·9753	17	·9160	51	·8357	85
·9741	18	·9135	52	·8331	86
·9728	19	·9113	53	·8305	87
·9716	20	·9090	54	·8279	88
·9704	21	·9069	55	·8254	89
·9691	22	·9047	56	·8228	90
·9678	23	·9025	57	·8199	91
·9665	24	·9001	58	·8172	92
·9652	25	·8979	59	·8145	93
·9638	26	·8956	60	·8118	94
·9623	27	·8932	61	·8089	95
·9609	28	·8908	62	·8061	96
·9593	29	·8886	63	·8031	97
·9578	30	·8863	64	·8001	98
·9560	31	·8840	65	·7969	99
·9544	32	·8816	66	·7938	100
·9528	33	·8793	67		

The contraction of volume suffered by various mixtures of alcohol and water, may be rendered obvious by comparing the actual specific gravities of such mixtures, with their calculated mean densities. In the accompanying engraving, in which the vertical lines represent the per centage of alcohol by weight, and the horizontal lines the specific gravities, the calculated mean specific gravities of the mixtures are seen to form a straight diagonal line from corner to corner, while the actual densities form an irregular curve with upward convexity, rising quickly to near its maximum deviation at 30 per cent., running almost parallel with the other line to 50 per cent., and thence declining until it reaches the extremity of the scale.

Fig. 84.

COMPARISON OF MEAN AND ACTUAL SPECIFIC GRAVITIES OF VARIOUS MIXTURES OF ALCOHOL AND WATER.



Silbermann's observations on a new instrument for ascertaining, by the amount of dilatation, the relative quantities of two liquids when mixed, and particularly mixtures of alcohol and water, are well worth transcribing. He states that various means have been suggested and employed for ascertaining the respective quantities of alcohol and water in mixtures of those liquids; but these are all found to possess many disadvantages. The distillation process is rarely employed on account of the great skill required in its application, and the length of time the operation demands before the results are arrived at. This method, at best, is only applied where accurate and scientific truth is required, irrespective of delay and toil. The density test is open to error on account of sirupy and other extractive matters being present, which would render the specific gravity of the impregnated liquid higher than that of alcohol, and thus prevent the true amount of spirit from being determined with strict accuracy; hence the Excise duty is, in consequence, evaded. Wines, tested by the density process, only indicate about one-half their strength; and for this reason **Gay-Lussac** combines, with the use of his alcoholometric areometer, the distillation test.

The boiling test of Field's hydrometer is likewise open to objections; for it is a known fact that steam, or vapor, may be heated beyond its point of generation, and that the thermometer, even when immersed in the liquid, may, under certain circumstances, stand several degrees above the real temperature, which would give rise to a difference in result of four alcoholometric degrees for every such extra indication. Besides, it is necessary to take the barometric variations into account in some better way than has hitherto been done. **Silbermann's** arrangement is said to obviate the evils attendant on those methods hitherto employed, and is based upon the dilatation of the alcoholic liquid. It is well known that between zero and 100° C.—212° Fahr.—of temperature, the dilatation of alcohol is triple that of water. This is much greater between 25° and 50° C.—45° and 90° Fahr.—and may thus be demonstrated:—Pour water at 45° Fahr. into a thermometer tube, so as to fill the reservoir, and a small portion of the tube up to a certain mark; then, on heating the thermometer to 90° Fahr. the water will rise a certain distance above the mark, and let this point be scratched on the tube; now, if the same quantity of pure alcohol, also at 45° Fahr., be substituted for the water, and heated to the temperature of 90°, it will be found to have risen three and a half times higher than the water. Any mixture of alcohol and water, on being treated in the same way, will be found to have a mean point of dilatation between these two, and will be nearer the one or the other, according as either liquid preponderates in the mixture. If, therefore, a series of mixtures of alcohol and water be made, beginning with—

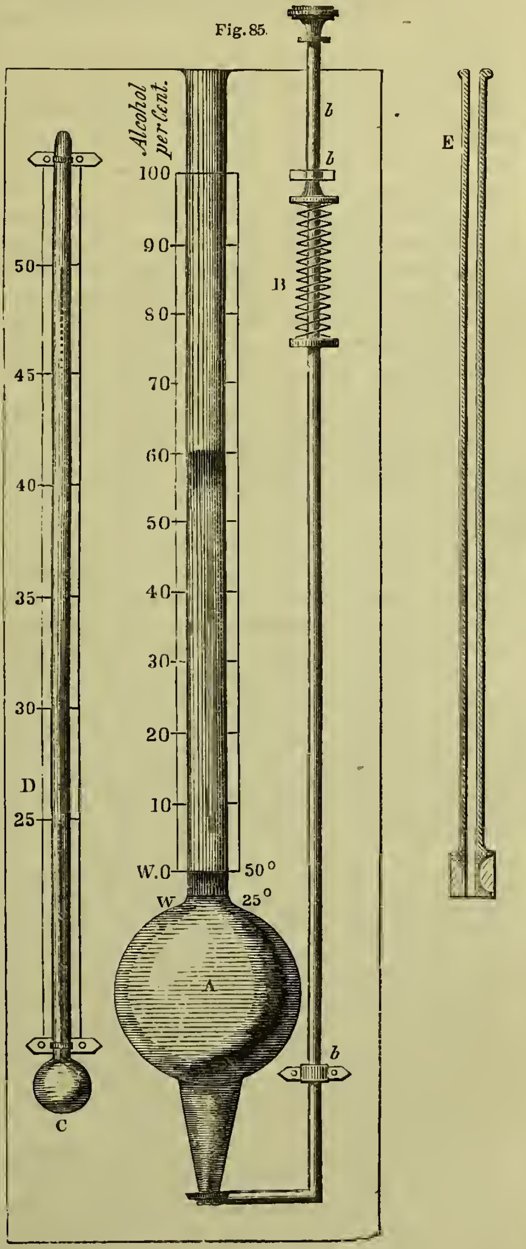
Water 100 parts,	.... Alcohol	0 parts;
do. 99 "	.... do.	1 "
do. 98 "	.... do.	2 "

and so on up to pure alcohol; and their several points of elevation at the respective temperatures, 45° and 90° Fahr., be carefully marked on the tube, a complete centesimal alcoholometric scale will be produced, which will indicate the quantity of alcohol contained in any mixture of alcohol and water, by introducing it at 45° and heating it to 90° Fahr.

The same process may be employed with regard to any other two liquids having points of dilatation differing between those of alcohol and water; but it will be understood that the same scale will not serve for more than one mixture. To adapt this principle to the ordinary purposes of alcoholometric measurement, SILBERMANN constructed a thermometer in a peculiar manner, thereby forming an instrument which he named a *dilatometer*, a view of which is presented to the reader in Fig. 85. The instrument is made by Messrs. CASARTELLI, of Liverpool and Manchester, who kindly furnished the drawing.

The form and arrangement of this apparatus are as follow:—A large bulb tube, A, of the form of a hydrometer, but tapering at the bottom and open at the top, is fixed to a metal plate, to which a thermometer, C, is also attached. The thermometer is graduated from 25° to 50° C.—45° to 90° F.—this being the working temperature of the dilatometer. Both the thermometer, and bulb of the apparatus, A, are immersed in the liquor to be tested; the former, to show the temperature, and the latter, to ascertain the expansion of the liquid when it is heated from 25° to 50° C. The expansion of distilled water between the extreme degrees of the thermometer, is marked on the stem of A by the figures 25 and 50; from the latter, the scale of degrees from 1 to 100 appended to the stem of the apparatus commences, and by it, the expansion of the alcoholic liquors is ascertained, when such liquors are heated from 25° to 50°. A valve of cork, or india-rubber, closes the tapering end of A; this valve is attached to a rod, *b b*, fastened to the supporting plate and connected to a spring, B. To cause the liquid under examination to flow, the spring valve is depressed by turning a screw of four threads, for the purpose of giving a quick motion, fitting in the upper part of the rod, and by reversing the motion of the screw the thermometer is closed; sometimes the rod may be made to terminate in a flattened end or cap, as the figure represents, and is moved by pressing it with the finger. As the liquids are often impregnated with air or gas, it is found necessary, before testing, to drive it off; the best method of effecting this is by means of a vacuum, which may be produced by the use of a small leather piston, E, working in the tube of the thermometer. This piston serves first, by suction, to fill the thermometer from below; and then, the lower part being closed, and the piston driven down, on raising it the air will be seen to separate from the liquid at all points; and after two or three more strokes of the piston the liquid may be completely purified, so that no more bubbles will rise during the operation to disturb the proper level of the column. To effect the withdrawal of the piston without any shock, so as not to divide the column abruptly, the piston-rod is made hollow throughout; the operator, having wetted his finger, applies it to the top of the piston-rod, in order to create a vacuum as he draws up the piston; he then withdraws it to readmit the air, and the piston is thus removed without a shock.

Fig. 85.



In order to form the vacuum properly, the liquid must be pumped in, until it rises to the piston-rod; on depressing the piston there is no air left underneath it.

The tube is now full of liquid, and by depressing the spring valve the liquid is run off, until it is as high as the lowest mark on the tube, when the temperature has been for two or three minutes at the lowest degree of the mercury thermometer. The inventor proposed this method to overcome the inconveniences to which those in general use are liable, and also as admitting of being applied to test wines as well as alcoholic liquors of any strength.

The method is based upon the principle of dilatation, and any salts or vegetal substances entering into the composition of, or otherwise present in wines or alcoholic liquors, do not materially affect the result, as all solutions expand in the same degree as water within the range of temperature which has been chosen. There is no occasion to fear the presence of any liquid more dilatable than alcohol, as liquids of such a nature are more expensive, and may, besides, be detected by their peculiar taste and smell. The same reasoning is also applicable to liquids less dilatable than water. The initial temperature, 25° C.—45° F.—was selected, because water may always be found below that temperature in summer. The final degree, 50° C.—90° F.—was chosen to avoid the effect of evaporation, which might diminish the actual degree if it approached too near the boiling point; and the range between this and 25° C.—45° F.—was found sufficient. Besides, these two points offer great facilities for the experiment, as, if it be conducted in a vessel containing about a quart of water, a small spirit lamp underneath it will be sufficient to maintain either the one or the other. The plate carrying the thermometers serves to agitate the water, that its temperature may be uniform throughout.

In Pennsylvania, Dicas' Liverpool patent hydrometer is adopted by Act, 15th of April, 1835, for the inspection of domestic distilled liquors. It is made of copper, with a stem pointed on the summit to receive brass poises, and is accompanied by a graduated ivory scale, with a sliding rule and thermometer to make corrections for temperature. By this instrument the strength of the spirit is indicated, as with Sykes' hydrometer, by a certain number above or below proof. The Act determines the standard of proof spirits to be as follows:—*If the liquor be hydrometer proof, or one hundred parts of spirit and one hundred parts of water, it shall be marked as liquor of the fourth proof; if it should be* 5° *below hydrometer proof, it shall be marked as of the third proof; if the liquor shall be* 10° *below hydrometer proof, it shall be marked as of the second proof; if the liquor shall be* 15° *below hydrometer proof, it shall be marked as of the first proof.—Booth.*

The proof spirit, which is, according to the preceding, composed of equal parts of alcohol and water, possesses a specific gravity, according to URE, of 0·9218 at 60° Fahr., and is centesimally composed of 55·76 of alcohol, and 44·24 of water by volume, or, by weight, of 48·03 of alcohol, and 51·97 of water.

The alcoholometer of TRALLES is used in Russia, those of CARTIERS and GAY-LUSSAC in France—all of which determine the per centage by volume of alcohol in a liquid, and by means of the calculation which is given in the foregoing, the per centage by weight is obtained. Having the per centage of alcohol by weight in a liquid, the quantity of water is likewise found by deducting the amount of alcohol from a hundred; but if the content of alcohol be determined per volume, this rule will not answer, since, on mixing alcohol and water, a contraction in volume takes place. Thus, if to fifty volumes of alcohol, fifty of water be added, the mixture will not make up a hundred volumes. In the distillation of spirit it is often necessary to reduce stronger alcoholic liquors to lower degrees of strength; and unless the amount of contraction be known, considerable labour will be attendant on bringing the mixture to the desired quality. The following table shows the relative volumes of alcohol and water which, when mixed, make up a hundred.

100 Volumes of spirit contain at 59°.		100 Volumes of spirit contain at 59°.	
Volume of alcohol.	Volume of water.	Volume of alcohol.	Volume of water.
100	0·00	45	58·64
95	6·18	40	63·44
90	11·94	35	68·14
85	17·47	30	72·72
80	22·87	25	77·24
75	28·19	20	81·72
70	33·14	15	86·20
65	38·615	10	90·72
60	43·73	5	95·31
55	48·77	0	100·00
50	53·745		

The annexed table of GAY-LUSSAC is more extensive on the subject, and shows the volume of water per cent. which is to be added to a liquor, of whatever strength, to bring it to any degree of dilution.

In this table the top horizontal column indicates the per centage by volume of the spirit which is required to be produced. The vertical columns under the top line specify the number of volumes of water which are to be added to a thousand volumes of alcohol, the richness of which is pointed out in the vertical column at the left-hand side of the table, in order to obtain the spirit properly diluted.

As illustrations facilitate the comprehension of the student in every problem, it may be well to follow the rule in this instance, and give a few examples taken from the table, in order that its application throughout may be more effectually understood. If it be required to prepare an alcohol of fifty per cent. from a liquor which is eighty per cent., the number, fifty, is sought in the top horizontal line of strengths, and in the vertical line under this figure the number six hundred and thirty-one is found in a horizontal line with eighty in the left hand vertical column; this figure indicates the number of volumes of water which are to be added to a thousand volumes of alcohol of eighty per cent. to bring it to the required degree of dilution.

Again, if it be requisite to bring a spirit of sixty per cent. to thirty per cent., the latter figure is found in the horizontal column at the top, and in the vertical column under it, in a line with sixty on the left hand, one thousand and seventeen is seen, which is the number of measures of water indispensable to reduce a thousand volumes of the strong liquor to the strength of thirty per cent.

TABLE OF GAY-LUSSAC FOR PROCURING A WEAKER ALCOHOL OF A CERTAIN STRENGTH FROM A STRONGER.

1000 vols. of alcohol of per cent. by vol.	Desired strength of the spirit. Per cent. by volume.																			
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
31	33																			
32	67	32																		
33	100	65	31																	
34	134	97	63	30																
35	167	129	94	61	30															
36	201	162	126	91	59	29														
37	234	194	157	122	89	58	28													
38	268	227	189	153	119	86	56	27												
39	302	260	220	183	148	115	84	55	27											
40	335	292	252	214	178	144	112	82	53	26										
41	369	325	284	245	208	173	140	109	80	52	25									
42	403	358	315	275	238	202	169	137	107	78	51	25								
43	437	390	347	306	268	231	197	164	134	104	76	50	24							
44	471	423	379	337	298	261	225	192	160	130	102	75	49	24						
45	505	456	411	368	328	290	254	220	187	157	127	99	73	47	23					
46	539	489	443	399	358	319	282	247	214	183	153	124	97	71	46	23				
47	573	522	474	430	388	348	310	275	241	209	179	149	122	95	70	46	22			
48	607	555	506	461	418	377	339	303	268	235	204	174	146	119	93	68	45	22		
49	641	588	538	492	448	407	367	330	295	262	230	200	171	143	116	91	67	44	21	
50	675	621	570	523	478	436	396	358	322	288	256	225	195	167	140	114	89	66	43	21
51	709	654	602	554	508	465	424	386	349	314	281	250	220	191	163	137	112	87	64	42
52	743	687	634	585	539	495	453	414	376	341	307	275	244	215	187	160	134	110	86	63
53	777	720	666	616	569	524	482	442	403	367	333	300	269	239	210	183	157	132	107	84
54	811	753	699	647	599	553	510	469	431	394	359	325	293	263	234	206	179	153	129	105
55	846	786	731	679	629	583	539	497	458	420	385	350	318	287	257	229	202	176	151	127
56	880	820	763	700	660	613	568	525	485	447	411	376	343	311	281	252	224	198	172	148
57	914	853	795	741	690	642	596	553	512	473	436	401	367	335	305	275	247	220	194	169
58	949	886	827	772	721	672	625	581	540	500	462	426	392	359	328	298	269	242	216	190
59	983	919	860	804	751	701	654	609	567	527	488	452	417	384	352	321	292	264	237	212
60	1017	953	892	835	781	731	683	637	594	553	514	477	442	408	375	345	315	286	259	233
61	1052	986	924	867	812	760	711	665	622	580	540	503	467	432	399	368	338	309	281	254
62	1086	1019	957	898	842	790	740	694	649	607	566	528	491	456	423	391	360	331	303	276
63	1121	1053	989	929	873	820	769	722	676	633	593	554	516	481	447	414	383	353	325	297
64	1155	1086	1022	961	904	850	798	750	704	660	619	579	541	505	471	438	406	376	346	318
65	1190	1120	1054	992	934	879	827	778	731	687	645	605	566	529	494	461	429	398	368	340
66	1224	1153	1086	1024	965	909	856	806	759	714	671	630	591	554	518	484	451	420	390	361
67	1259	1187	1119	1055	995	939	885	834	786	741	697	656	616	578	542	508	474	443	412	383
68	1293	1220	1151	1087	1026	969	914	863	814	767	723	681	641	603	566	531	497	465	434	404
69	1328	1254	1184	1118	1056	998	943	891	841	794	750	707	666	627	590	554	520	487	456	426
70	1363	1287	1216	1150	1087	1028	972	919	869	821	776	732	691	652	614	578	543	510	478	447
71	1397	1321	1249	1182	1118	1058	1001	948	897	848	802	758	716	676	638	601	566	532	500	469
72	1432	1354	1282	1213	1149	1088	1030	977	924	875	828	784	741	701	662	625	589	555	522	491
73	1467	1388	1314	1245	1180	1118	1060	1005	952	902	855	810	767	725	686	648	612	578	544	512
74	1502	1422	1347	1277	1211	1148	1089	1033	980	929	881	835	792	750	710	672	635	600	567	534
75	1536	1456	1380	1309	1241	1178	1118	1061	1008	956	908	861	817	775	734	695	658	623	589	556
76	1571	1489	1413	1340	1272	1208	1147	1089	1035	983	934	887	842	799	758	719	681	645	611	578
77	1606	1523	1445	1372	1303	1238	1177	1118	1063	1011	961	913	867	824	782	743	705	668	633	599
78	1641	1557	1478	1404	1334	1268	1206	1147	1091	1038	987	939	893	849	807	766	728	691	655	621
79	1676	1591	1511	1436	1365	1299	1235	1175	1119	1065	1014	965	918	873	831	790	751	713	678	643
80	1711	1625	1544	1468	1396	1329	1265	1204	1147	1092	1040	991	943	898	855	813	774	736	700	665
81	1746	1658	1577	1500	1427	1359	1294	1233	1175	1119	1067	1017	969	923	879	837	797	759	722	687
82	1781	1692	1610	1532	1458	1389	1323	1261	1203	1147	1093	1043	994	948	904	861	821	782	745	709
83	1816	1726	1643	1564	1489	1419	1353	1290	1231	1174	1120	1069	1020	973	928	885	844	805	767	731
84	1851	1760	1676	1596	1521	1450	1382	1319	1259	1201	1147	1095	1045	998	952	909	867	828	789	753
85	1886	1794	1709	1628	1552	1480	1412	1348	1287	1229	1173	1121	1071	1023	977	933	891	851	812	775
86	1921	1828	1742	1660	1583	1510	1442	1376	1315	1256	1200	1147	1096	1048	1001	957	914	874	834	797
87	1956	1863	1775	1692	1614	1541	1471	1405	1343	1284	1227	1173	1122	1073	1026	981	938	897	857	819
88	1992	1897	1808	1724	1645	1571	1501	1434	1371	1311	1254	1200	1147	1098	1050	1005	961	920	880	841
89	2027	1931	1841	1757	1677	1602	1531	1463	1400	1339	1281	1226	1173	1123	1075	1029	985	943	902	863
90	2062	1966	1875	1789	1708	1633	1561	1492	1428	1367	1308	1252	1199	1148	1100	1053	1009	966	925	886

Table of Gay-Lussac for procuring a weaker alcohol of a certain strength from a stronger.—*Continued.*

1000 vols. of alcohol of per cent. by vol.	Desired strength of the spirit.																								
	Per cent. by volume.																								
	50	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*59*	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
51	21																								
52	41	20																							
53	62	41	20																						
54	83	61	40	19																					
55	103	81	60	39	19																				
56	124	102	80	59	38	19																			
57	145	122	100	78	58	38	19																		
58	166	142	120	99	77	57	37	18																	
59	187	163	140	118	96	76	56	37	18																
60	208	183	160	137	116	95	74	55	36	18															
61	229	204	180	157	135	114	93	73	54	35	17														
62	250	225	200	177	155	133	112	92	72	53	35	17													
63	271	245	221	197	174	152	131	110	90	71	52	34	17												
64	292	266	241	217	194	171	150	128	109	89	70	52	34	17											
65	313	286	261	237	213	190	168	147	127	107	88	69	51	33	16										
66	334	307	281	256	233	209	187	166	145	125	105	86	68	50	33	16									
67	355	328	301	276	252	229	206	184	163	143	123	104	85	67	49	32	16								
68	376	348	322	296	272	248	225	203	181	160	140	121	102	84	66	49	32	16							
69	397	369	342	316	291	267	244	221	200	178	158	138	119	101	82	65	48	32	16						
70	418	390	362	336	311	286	263	240	218	196	176	156	136	117	99	81	64	47	31	15					
71	439	411	383	356	331	306	282	259	236	214	193	173	153	134	116	98	80	63	47	31	15				
72	460	431	403	376	350	325	301	277	255	232	211	191	171	151	132	114	97	79	63	46	30	15			
73	482	452	424	396	370	344	320	296	273	251	229	208	188	168	149	131	113	95	78	62	46	30	15		
74	503	473	444	416	390	364	339	315	291	269	247	226	205	185	166	147	129	111	94	77	61	45	30	15	
75	524	494	465	437	409	383	358	333	310	287	265	243	222	202	183	164	145	127	110	93	76	60	45	29	14
76	546	515	485	457	429	403	377	352	328	305	283	261	240	219	199	180	162	143	126	109	92	75	60	44	29
77	567	536	506	477	449	422	396	371	347	323	300	278	257	236	216	197	178	159	142	124	107	91	75	59	44
78	588	557	527	497	469	442	415	390	365	341	318	296	274	253	233	213	194	176	157	140	123	106	90	74	58
79	610	578	547	517	489	461	434	409	384	360	336	314	292	271	250	230	211	192	173	155	138	121	105	88	73
80	631	599	568	538	509	481	454	428	402	378	354	331	309	288	267	247	227	208	189	171	153	136	120	103	87
81	653	620	588	558	529	500	473	447	421	396	372	349	327	305	284	263	243	224	205	187	169	152	135	118	102
82	674	641	609	578	549	520	492	465	440	415	390	367	344	322	301	280	260	240	221	203	184	167	150	133	117
83	696	662	630	599	569	540	512	485	458	433	409	385	362	339	318	297	276	256	237	218	200	182	165	148	131
84	717	683	651	619	589	559	531	504	477	451	427	403	379	357	335	313	293	273	253	234	216	198	180	163	146
85	739	705	671	640	609	579	550	523	496	470	445	421	397	374	352	330	309	289	269	250	231	213	195	178	161
86	761	726	692	660	629	599	570	542	515	488	463	438	415	391	369	347	326	305	285	266	247	229	211	193	176
87	782	747	713	681	649	619	589	561	534	507	481	456	432	409	386	364	343	322	302	282	263	244	226	208	191
88	804	769	734	701	669	639	609	580	553	526	500	474	450	426	403	381	359	338	318	298	279	260	241	223	206
89	826	790	755	722	690	659	629	600	572	544	518	493	468	444	421	398	376	355	334	314	295	275	257	239	221
90	848	812	777	743	710	679	648	619	591	563	537	511	486	462	438	415	393	372	351	331	311	291	273	254	236

Table of Gay-Lussac for procuring a weaker alcohol of a certain strength from a stronger.—*Concluded.*

1000 vols. of alcohol of per cent. by vol.	Desired strength of the spirit.														
	Per cent. by volume.														
	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
76	14														
77	29	14													
78	43	28	14												
79	57	43	28	14											
80	72	57	42	28	14										
81	86	71	56	42	27	14									
82	101	85	70	56	41	27	13								
83	116	100	85	70	55	41	27	13							
84	130	114	99	84	69	55	40	27	13						
85	145	129	113	98	83	68	54	40	26	13					
86	159	143	127	112	97	82	68	54	40	26	13				
87	174	158	142	126	111	96	81	67	53	39	26	13			
88	189	172	156	140	125	110	95	81	66	53	39	26	13		
89	204	187	171	155	139	124	109	94	80	66	52	39	26	13	
90	219	202	185	169	153	138	123	108	94	79	66	52	39	26	13

The tables for determining the per centage of alcohol, as given in the preceding pages, cannot all be consulted when ascertaining the quantity of spirit in a liquid, and from this fact they might be looked upon as unnecessary; they serve, however, to give a clear view of the composition of alcoholic liquors of different states of dilution, and under the influence of various degrees of temperature and pressure, enabling the diligent student to draw up tables of great accuracy and of less extent, for reference on all ordinary occasions. This arrangement has been already effected, as in Sykes' and many other tables. From what has been said upon the properties of alcohol at the beginning of the subject, in relation to its real specific gravity, as determined by **Drinkwater**, it will be observed that none of the enumerated tables are strictly correct, since the density of absolute alcohol—to which all the other densities bear a proportionate analogy—stated in them, is considerably higher than that assigned to it by the forementioned chemist.

Hence the necessity of constructing new tables, corresponding to the density of absolute alcohol, as found by recent experiments, becomes urgent.

The annexed is a contraction of the foregoing table of GAY LUSSAC, showing the dilution per cent. in reducing liquors to a lower strength. The upper horizontal column contains the per cent. of the stronger alcohol, and the vertical columns below, the bulk of water which is to be added to 100 volumes of it, to produce spirit of the quality indicated in the left-hand column.

Desired strength in per cent.	100 vols. of alcohol of per cent. by vol.								
	90	85	80	75	70	65	60	55	50
85	6·56								
80	13·79	6·83							
75	21·89	14·48	7·20						
70	31·05	23·14	15·35	7·64					
65	41·53	33·03	24·66	16·37	8·15				
60	53·65	44·48	35·44	26·47	17·58	8·76			
55	67·87	57·90	48·07	38·32	28·63	19·02	9·47		
50	84·71	73·90	63·04	52·43	41·73	31·25	20·47	10·35	
45	105·34	93·30	81·38	69·54	57·78	46·09	34·46	22·90	11·41
40	130·80	117·34	104·01	90·76	77·58	64·48	51·43	38·46	25·55
35	163·28	148·01	132·88	117·82	102·84	87·93	73·08	58·31	43·59
30	206·22	188·57	171·05	153·61	136·04	118·94	101·71	84·54	67·45
25	266·12	245·15	224·30	203·53	182·83	162·21	141·65	121·16	100·73
20	355·80	329·84	304·01	278·26	252·58	226·98	201·43	175·96	150·55
15	505·27	471·00	436·85	402·81	368·83	334·91	301·07	267·29	233·64
10	804·54	753·65	702·89	652·21	601·60	551·06	500·59	450·19	399·85

Adulterations of Spiritous Liquors and their detection.—The sophistication of alcoholic liquors has been practised to give to many solutions containing very little spirit, the appearance and some of the physical properties which would be conferred by alcohol; and adulterations have also been practised with a view, as it were, of veiling the quantity of spirit.

Such proceedings are invariably the result of dishonest trade; though, of the two evils, the former is the viler in its tendency. The counterfeiting of strong alcoholic liquors apparently as weaker spirit, or passing them off as quite a different liquid, was fostered in the wine-growing countries of the continent, where large quantities of brandy were manufactured; and before the proper means of detection were at command, the strongest brandy was often sold to the merchants disguised as ordinary wine, or a much weaker spirit, and by this means the *Octroi* duties were eluded. The imposition had long been practised after the introduction of various hydrometric or alcoholometric scales for the determination of the amount of alcohol in spiritous liquors; for, as most of these were on the principle of the gravity test, advantage was taken by adding various substances which would heighten the density, and make it appear that the spirit was much more aqueous than it really was. In other instances the spirit was passed upon the Excise as quite a different article, sometimes as a deodorising agent, while at other times it was made to assume the character of wood naphtha. Expedients such as these have been countenanced in this country; and in the large towns where much alcoholic liquor is consumed, the contrary vice of vending drinks to the public which are said to be alcoholic, but in reality contain little or no spirit, is frequently practised among some of the liqueur fabricators, who add supervacaneous substances, making an *olla podrida.* To defraud the Excise, sugar, or other extractive matter, is added to the spirit, to increase the specific gravity, and sometimes wood-spirit, turpentine, pyroligneous acid, chlorine water, or other bodies possessing a strong odor, are added to the liquor, and in this case it is represented as not being alcoholic.

The detection of these frauds is, for the most part, easy and expeditious. In case sugar, extractive matter, pyroligneous acid, turpentine, *et cetera,* are suspected, it is only necessary to distil a portion of the liquid, and determine the density of the distillate by the hydrometer, or specific gravity bottle, and on referring to the corresponding gravity in either of the tables already given, under *alcoholometry,* the corresponding value of alcohol is found. When a liquor is disguised as wood naphtha, it is more difficult to determine the amount of alcohol; distillation, as in the forementioned instance, is ineffectual, for the naphtha passes over at even a lower degree of heat than the alcohol. The following is the method recommended by Dr. URE for the detection of alcohol in wood or coal naphtha, or pyroligneous acid:—

A small quantity of nitric acid of specific gravity 1·45, is first to be added to the spirit under examination, and if alcohol be present, it will immediately produce an effervescence of nitrous ether gas, which may be recognized as such by its odor. The mixture is then treated with a solution of mercury in nitric acid—which is prepared by dissolving one hundred grains of mercury in one fluid ounce of this acid, with the help of heat. Soon after this addition, and especially on raising the temperature, the mixture begins to effervesce and to evolve thick ethereal vapors; should the effervescence become too violent, it must be quelled by immediately withdrawing the fire, and cooling the vessel. A yellowish grey precipitate falls down, which is fulminate of mercury, and which should be immediately separated by decanting or filtering the liquor from it, washing the precipitate on the filter with a little distilled water, and carefully drying it at a heat which must not exceed 100° Fahr.; after which it is weighed. The quantity of fulminate of mercury obtained is nearly equal to that of the alcohol contained in the wood-spirit; and at any rate, the formation of the detonating salt is quite characteristic of the presence of alcohol, since wood-spirit treated by nitric acid in the presence of mercury or silver, produces neither fulminate of silver nor fulminate of mercury.

In applying this test, the greatest care should be exercised, and every precaution taken to prevent contact of any hard body with the precipitate, since the fulminates of silver and mercury, and especially the former, are so very explosive; the fulminate of silver has been known to explode by contact with a glass rod, even under water; the fulminate of mercury is less explosive, and on that account is preferred. For the purpose of collecting these compounds, the feather of a quill should be used; and if the quantity is at all considerable, that is, if it exceeds a few grains, it should be collected in several filters so as to handle only small portions at a time. During the evolution of the ethereal vapors before alluded to, all approach of flame should be carefully avoided.

The same chemist gives the following as the principal tests whereby to discern alcohol from wood naphtha, and also whether the latter is genuine or mixed with alcohol:—

1st. The boiling point of pure wood naphtha spirit is at least 20° Fahr. below that of alcohol of the same density, and it exhales the characteristic, pungent, and offensive odor of aldehyde. In the course of his experiments he found the boiling point of—

Wood-spirit, of specific gravity, ·870, to be	144°	Fahr.
Alcohol, of like gravity,....................	180°	,,
Wood-spirit, of specific gravity, ·832,.....	140°	,,
Alcohol, of the same density,............	171·1°	,,

If ten per cent. of naphtha be mixed with alcohol, the boiling point is lowered at least 6° Fahr.

2nd. When rectified naphtha is distilled at the temperature of boiling water from a large quantity of lime, the distillate is unchanged in its gravity, whilst if alcohol, or a mixture of alcohol and naphtha, be subjected to the same treatment, the first portions that come over are nearly absolute, and stand at a density below ·800, and contain, at 60° Fahr., about seventy per cent. over proof. The reason of this characteristic difference seems to be that naphtha possesses a stronger affinity for water than alcohol.

3rd. When water is added to alcohol, the specific gravity of the liquor becomes reduced in a less proportion than when wood-spirit of the same gravity as the alcohol is diluted with the same quantity of water. Thus, for example, if alcohol of a given density is diluted with a certain quantity of water, so as to bring it to specific gravity 0·920, wood-spirit of the same original gravity, and diluted with the same quantity of water, will become of specific gravity 0·926 or 0·927.

Dr. **Ure** says that caustic potassa in powder is the most delicate test for the detection of wood-spirit in alcohol; for if wood-spirit is present the liquor assumes then a brown color, whilst pulverized potassa does not alter the color of pure alcohol, even after several hours, and it is only after a whole day's contact that a feeble yellowish tinge is then developed. But if the alcohol contains only two per cent., or even one per cent. of wood-spirit, it turns yellowish in the course of ten minutes, and brown in half an hour.

On the other hand, where brandies, gins, and other alcoholic liquors are artificially made by admixture of various ingredients with alcohol, as is directed under these heads, it is not uncommon to find that the alcohol, in such compounded articles, is attenuated as low as possible, and that the agreeableness of taste, and the pungency of flavor peculiar to the genuine beverages, are conferred by means of pepper, cayenne, or other acrid substances. These sophistications are discovered by evaporating a known quantity of the liquid to dryness at a gentle heat; the impure matters remain, and may be recognised by their flavor.

Various alcoholometers have been lately constructed for the purpose of ascertaining the content of alcohol, irrespective of the density. The first instrument of this description was constructed, as already stated, by M. **Brossard-Vidal**, and was improved by **Conaty**. **Ure**'s modification of this instrument, which is given at page 136, determines the amount of alcohol from the boiling point; and more recently, **Silbermann**, to obviate the discrepancies attendant upon other methods, constructed his dilatometer, which has been likewise described. These instruments determine the amount of alcohol, without referring to the foreign bodies which may have been present in the liquor.

Acetates of copper and lead are rarely detected in brandies, owing to the repeated distillations to which the spirit is subjected, but where the old stills are employed, the solder connecting the seams of the still is dissolved by the small quantity of acetic acid present in the liquors; it has likewise been known that acetate of lead—sugar of lead—has been added to facilitate the clarifying process. Liquors thus treated may prove extremely pernicious, since acetate of lead is highly poisonous. By filtering the brandy through animal charcoal, and adding sulphuric acid to the clear liquor, if the lead has been present in excess, a white precipitate appears; if there is no precipitate, a stream of sulphide of hydrogen is to be transmitted through the liquid, and if any lead is present, a black precipitate, or coloration is produced. Should a white precipitate be obtained by the action of sulphuric acid, or sulphate of soda, on the brandy, it is turned black by the addition of sulphide of ammonium, and if the precipitate should be bulky it may be mixed with a little carbonate of soda, and reduced on charcoal before the blowpipe to a globule of metal.

Copper may be detected by filtering a portion of the brandy through animal charcoal, to decolorize it; ammonia is then to be added to the clear liquor, to which it will impart a blue tinge, if copper be present, at least in sufficient quantity. Several hours are sometimes requisite to determine this appearance. The presence of copper may also be detected by immersing a blade of perfectly clean iron in the brandy, and leaving it there for a few hours, when it will be found coated with a film of metallic copper. The brandy, first decolorized by animal charcoal, may also be tested for copper by a solution of ferrocyanide of potassium, which will produce a reddish brown precipitate with this metal.

Statistics of the Spirit Trade of Great Britain and Ireland, from the Parliamentary Reports of the Inland Revenue.—Without recurring to the period when the English distiller had to pay a duty of eleven shillings and eightpence farthing on every gallon of spirits distilled, or to the time that the Scotch distiller had to contend with a revenue rental of one hundred and sixty-two pounds sterling upon every gallon capacity of his still, it may be interesting to give a brief statement of the extent of the spirit trade, and the amount of revenue which through this channel flows into the Exchequer. Every English distiller has now to pay a licence duty of ten guineas before he can lawfully conduct operations, and afterwards a duty of eight shillings per imperial gallon of spirits, proof strength, which he produces.

The Scotch and Irish distillers have to pay the same licence fee as the English, and in addition to this the Scotch distiller, like the English, pays a duty of eight shillings per imperial gallon of proof strength, being an increase of four shillings and fourpence per gallon above what was paid by the Scotch distiller previous to the 1st of April, 1853; the Irish manufacturer also pays a duty of six shillings and twopence per gallon, proof strength. Regarding the spirit imported from Guernsey, Jersey, Alderney, and Sark, into England, Scotland, and Ireland, the Government enjoins that a countervailing duty of nine shillings be paid upon every gallon of proof strength, and of the quality of plain British spirit, that enters England or Scotland; and of seven shillings and twopence per proof gallon upon what is brought into Ireland.

By an Act passed in 1855, the duties on spirits in England and Scotland are equalized; and the countervailing duty on spirit imported from Ireland into England or Scotland was regulated as follows:—

Articles enumerated. For every gallon thereof removed.	Countervailing Duties from Ireland to England or Scotland. £ s. d.
Ether,	0 4 7
Sweet spirit of nitre,	0 2 9
Camphorated spirit,	
Lavender water, and other perfumes, being spirits scented with essential oils, flowers, and other ingredients,	
Compound spirit of lavender,	
Spirit of rosemary,	
Spirit of ammonia,	
Sal volatile,	
Friars' balsam,	
Compound tincture of benzoin,	
Tinctures of asafœtida, castor, kino, guaiacum, myrrh, and ginger,	
Spirit varnishes,	
Other tinctures and medicated spirits,	0 1 10
Made wines,	0 0 2¾

An important feature in the Act of 1853 was the redress of a grievance under which the distiller labored, from being required to pay the full amount of duty on bonded spirit, without any allowance being made for the waste by evaporation. When liquors remained for a long time in store, this loss amounted to something considerable, and for which the owner had to pay the same duty as for the original quantity of spirit. A drawback of a quarter of a gallon is now allowed for every hundred gallons of spirit remaining in bond for seven days; and for longer periods, as follows:—

For a period over 7 days,	and under 14 days,	½ a gallon.
14 "	" 1 month,	¾ "
1 month,	" 2 "	1 "
2 "	" 3 "	1¼ "
3 "	" 6 "	1¾ "
6 "	" 9 "	2¼ "
9 "	" 12 "	2¾ " .

Above this time an additional allowance of three-fourths of a gallon is made for every six months, or multiple thereof up to five years, during which the above quantity of spirit may be warehoused.

The number of distillers and rectifiers in the United Kingdom, during the series of years, from 1846 to 1854, both inclusive, is shown in the following table:—

Year ending 5th Jan.	England.	Scotland.	Ireland.	Total.
1846	94	174	100	377
1847	93	176	93	367
1848	90	169	96	355
1849	85	168	89	342
1850	86	164	87	337
1851	86	166	88	340
1852	85	159	80	324
1853	88	149	72	309
1854	89	145	71	305

The licence duty for these distilleries during the same period, in—

	England.	Scotland.	Ireland.	Total.
1846,	£987 0 0	£1921 10 0	£1050 0 0	£3958 10 0
1847,	976 10 0	1900 10 0	976 10 0	3853 10 0
1848,	945 0 0	1837 10 0	1008 0 0	3790 10 0
1849,	892 10 0	1827 0 0	934 10 0	3654 0 0
1850,	903 0 0	1753 10 0	913 10 0	3570 0 0
1851,	903 0 0	1743 0 0	924 0 0	3570 0 0
1852,	892 10 0	1669 10 0	840 0 0	3402 0 0
1853,	924 0 0	1564 10 0	756 0 0	3244 10 0
1854,	934 10 0	1522 10 0	745 10 0	3202 10 0

The revenue arising from home-made spirits in the preceding years:—

	England.	Scotland.	Ireland.	Total.
1846,	£3,595,315	£1,278,766	£1,060,276	£5,934,359
1847,	3,293,589	1,135,428	804,984	5,234,003
1848,	3,373,525	1,200,501	943,057	5,517,084
1849,	3,546,023	1,271,417	929,777	5,747,218
1850,	3,654,842	1,305,880	987,744	5,948,467
1851,	3,758,185	1,252,296	1,006,735	6,017,218
1852,	3,846,404	1,314,869	1,094,434	6,255,708
1853,	4,053,870	1,433,400	1,273,151	6,760,421
1854,	4,265,097	1,806,934	1,588,745	7,660,776

In comparing the indications of the preceding three tables, it will be observed from the first that the total number of distillers and rectifiers in the United Kingdom, which, in 1846, amounted to three hundred and seventy-seven, was only three hundred and five in 1854, exhibiting therefore a decrease of seventy-three—equivalent to nineteen per cent.—during nine years. In Ireland, the decrease was twenty-nine per cent., in Scotland sixteen per cent., and in England only five per cent. At the same time it appears from the last table, that while the number of the rectifiers and distillers was diminishing to that amount, the total revenue derived from home-made spirits during the same period was steadily increasing, showing that while the establishments were being reduced in number, they were greatly extending in magnitude.

Exclusive of rectifiers, the number of distillers licensed in 1855–56, in the three kingdoms, was as follows:—England, 11; Scotland, 134; Ireland, 39.

The following table exhibits a return of the quantity of spirit distilled, and the quantity charged with duty for home consumption in the United Kingdom, from 1800 to 1854, both inclusive, distinguishing the quantities so distilled and consumed in England, Scotland, and Ireland respectively:—

Years.	Number of imperial gallons of spirit distilled in				Number of imperial gallons of spirit charged with duty for consumption in			
	England.	Scotland.	Ireland.	United Kingdom.	England.	Scotland.	Ireland.	United Kingdom.
1800	4,352,788	1,277,696	There are no records from which an account for this period can be furnished.		4,352,888	1,277,596	1,330,500	6,960,984
1801	2,478,289	295,931			2,555,920	295,931	355,106	3,206,957
1802	3,384,742	1,344,835	4,475,458	9,205,035	3,981,072	1,158,558	4,715,098	9,854,728
1803	4,184,034	2,247,000	4,795,109	11,226,143	5,370,377	2,022,409	4,343,095	11,735,881
1804	2,586,586	2,478,003	4,205,830	9,270,419	3,690,745	1,889,757	3,543,599	9,124,101
1805	2,869,520	2,617,508	4,611,734	10,098,762	4,932,645	1,625,987	3,686,233	10,244,865
1806	2,425,007	2,788,274	4,059,914	9,273,195	4,094,985	1,812,237	3,858,107	9,765,329
1807	3,581,043	3,397,204	5,305,632	12,283,879	4,747,365	2,653,478	5,597,204	12,998,047
1808	3,847,127	3,589,435	4,524,475	11,961,037	5,390,884	2,683,342	3,575,430	11,649,656
1809	3,307,039	2,610,512	1,288,758	7,206,309	4,035,825	1,315,135	1,360,386	6,711,346
1810	3,898,966	2,171,513	4,301,026	10,371,505	4,787,555	1,748,140	4,728,522	11,264,217
1811	4,116,833	2,859,861	6,187,779	13,164,473	4,776,330	1,951,092	6,378,479	13,105,901
1812	3,938,793	3,001,677	4,053,600	10,994,070	5,242,470	1,687,905	4,009,301	10,939,676
1813	3,859,095	1,842,817	3,595,030	9,296,942	4,292,477	1,234,291	3,158,693	8,685,461
1814	3,670,714	2,988,323	5,947,658	12,606,695	4,959,965	1,474,187	5,393,713	11,824,865
1815	3,402,489	3,024,430	4,468,106	10,895,025	5,468,987	1,591,148	4,323,844	11,383,979
1816	3,486,478	2,145,366	4,562,286	10,194,130	4,745,484	918,859	3,557,200	9,221,543
1817	2,907,732	3,060,499	2,692,182	8,660,413	4,133,063	1,906,950	3,586,932	9,626,945
1818	3,782,512	3,062,820	4,474,777	11,320,109	5,259,662	2,066,988	4,284,347	11,610,997
1819	2,815,716	3,547,199	3,879,216	10,242,131	4,146,505	2,125,150	3,676,516	9,948,171
1820	2,866,684	3,278,129	4,607,296	10,752,109	4,284,798	1,863,987	3,299,650	9,448,435
1821	2,662,852	3,216,858	3,627,552	9,507,262	4,125,616	2,385,495	3,311,462	9,822,573
1822	3,181,026	3,337,850	4,135,045	10,653,921	4,694,055	2,225,124	2,910,483	9,829,662
1823	2,134,913	3,083,515	2,844,677	8,063,105	3,803,312	2,303,286	3,590,376	9,696,974
1824	2,894,309	5,908,373	6,361,248	15,163,930	4,392,611	4,350,301	6,690,315	15,433,227
1825	2,039,771	8,224,807	8,835,027	19,099,605	3,684,049	5,981,549	9,262,744	18,928,342
1826	3,209,044	8,563,994	9,046,959	20,819,997	7,407,204	3,988,788	6,834,867	18,230,859
1827	3,451,620	7,243,819	7,283,317	17,978,756	6,671,562	4,752,199	8,260,664	19,684,425
1828	3,974,785	10,117,047	9,725,259	23,817,091	7,759,687	5,716,180	9,937,903	23,413,770
1829	3,860,542	9,649,070	9,208,538	22,718,150	7,700,766	5,777,280	9,212,224	22,690,270
1830	4,656,443	9,883,413	8,694,742	23,234,598	7,732,101	6,007,631	9,004,539	22,744,271
1831	3,444,792	9,510,268	8,786,341	21,741,401	7,434,047	5,700,689	8,710,672	21,845,408
1832	3,788,068	7,979,088	9,260,920	21,028,076	7,281,900	5,407,097	8,657,756	21,346,753
1833	4,591,223	9,146,889	9,509,774	23,247,886	7,717,303	5,988,556	8,168,596	21,874,455
1834	4,652,838	9,193,091	9,370,343	23,216,272	7,644,301	6,045,043	9,708,416	23,397,760
1835	4,327,425	9,133,449	11,167,580	24,628,454	7,315,053	6,013,932	11,381,223	24,710,208
1836	5,088,340	10,222,650	11,894,169	27,205,159	7,875,702	6,620,826	12,248,772	26,745,300
1837	4,614,196	9,012,485	10,980,910	24,607,591	7,133,869	6,124,035	11,235,635	24,493,539
1838	5,776,411	9,047,199	11,064,820	25,888,430	7,930,490	6,259,711	12,296,342	26,486,543
1839	5,685,698	9,871,653	10,254,591	25,811,942	8,186,552	6,188,582	10,815,709	25,190,843
1840	5,918,435	8,821,530	7,281,429	22,021,394	8,278,148	6,180,138	7,401,051	21,859,337
1841	5,919,207	8,504,333	6,359,124	20,782,664	8,166,985	5,989,905	6,485,443	20,642,333
1842	6,008,456	7,658,985	5,315,090	18,982,531	7,956,054	5,595,186	5,290,650	18,841,890
1843	5,800,509	7,650,272	5,550,706	19,001,487	7,724,051	5,593,798	5,546,483	18,864,332
1844	5,433,843	8,321,306	6,878,243	20,633,392	8,234,440	5,922,948	6,451,137	20,608,525
1845	5,866,593	9,418,663	8,397,459	23,682,715	9,076,381	6,441,011	7,605,196	23,122,588
1846	5,624,868	9,735,303	8,658,879	24,019,050	9,179,530	6,975,091	7,952,076	24,106,697
1847	5,356,794	8,542,219	5,737,687	19,636,700	8,409,165	6,193,249	6,037,383	20,639,797
1848	5,503,238	9,600,321	8,126,507	23,230,066	8,581,327	6,548,190	7,072,933	22,202,450
1849	5,573,411	10,846,634	8,355,083	24,775,128	9,053,676	6,935,003	6,973,333	22,962,012
1850	5,913,424	11,638,429	8,293,034	25,844,887	9,331,512	7,122,987	7,408,086	23,862,585
1851	6,127,181	10,380,972	8,035,504	24,543,657	9,595,368	6,830,710	7,550,518	23,976,596
1852	6,363,276	9,942,218	8,117,708	24,423,202	9,820,608	7,172,015	8,208,256	25,200,879
1853	7,308,670	10,359,926	8,772,961	26,441,557	10,350,307	6,534,648	8,136,362	25,001,317
1854	6,831,664	9,862,318	8,259,930	25,003,912	10,889,611	6,553,239	8,440,734	25,883,584

It will be observed by consulting the foregoing table, based upon parliamentary returns, that the spirit distilled in England in the early part of this century, was equal to that of Ireland, and greater than the total produce of Scotland. Coming down to later years, however, a very remarkable difference is apparent between the quantities afforded by the three nations, particularly as regards Scotland and England, for in 1850 there was nearly double the number of gallons distilled in the former, as in the latter country. It is obvious that this apparent anomaly is to be attributed to the fact, that in Scotland and Ireland the revenue returns embraced but a small proportion of the spirit actually distilled in 1800, and few succeeding years, as the business was at that time chiefly conducted by smugglers or illicit distillers.

Selecting, as an average example, the year 1852, the following are the relative proportions of spirit extracted from the different ingredients used:—

	England. gallons.	Scotland. gallons.	Ireland. gallons.
From malt only,........	—	....5,276,266....	10,056
From a mixture of malt with unmalted grain,	5,155,069....	2,363,259....	7,841,915
From a mixture of sugar and molasses with unmalted grain,.......	1,208,207....	2,295,901....	265,737
From molasses,..........	—	6,792....	—
	6,363,276	9,942,218	8,117,708

Spirit made in Scotland from malt only is entitled to an abatement of sevenpence-halfpenny per gallon, and 5 per cent. when exported, used as ship stores, or when removed to a warehouse in England or Ireland. A like drawback is allowed to distillers in England and Ireland, provided they work under the same regulations as Scotch distillers, and when they warehouse specifically for exportation, or for ships' stores.

To complete the statistics of the spirit trade, it only remains to annex a return of the quantity of foreign and colonial spirits of all sorts entered for home consumption in the United Kingdom, in each year, from 1800 to 1854, both inclusive; distinguishing, in this case also, the quantities consumed in England, Scotland, and Ireland respectively.

Years.	Number of imperial gallons, including over-proof, of foreign and colonial spirits entered for home consumption in			
	England.	Scotland.	Ireland.	United Kingdom.
1800	3,641,684	354,010	1,034,823	5,030,517
1801	3,595,063	634,559	1,364,261	5,593,883
1802	4,187,687	824,320	729,635	5,741,642
1803	4,677,921	577,703	296,259	5,551,883
1804	2,817,014	155,296	202,879	3,175,189
1805	3,283,811	225,376	148,724	3,657,911
1806	3,789,704	289,589	183,483	4,262,776
1807	3,704,665	355,354	228,589	4,288,608
1808	4,357,886	355,025	378,359	5,091,270
1809	3,200,917	325,876	1,132,816	4,659,609
1810	4,421,249	401,408	358,741	5,181,398
1811	3,766,977	353,163	154,547	4,274,687
1812	3,380,996	298,451	291,415	3,970,862
1813	3,278,766	246,808	474,489	4,000,063
1814	3,948,581	313,994	104,392	4,366,967
1815	3,759,409	322,606	74,439	4,156,454
1816	2,950,113	218,329	28,123	3,196,565
1817	2,883,443	233,682	36,734	3,153,859
1818	3,017,535	237,519	30,630	3,285,684
1819	3,242,207	186,886	35,939	3,465,032
1820	3,241,898	174,764	29,798	3,446,460
1821	3,135,915	172,790	29,010	3,337,715
1822	3,155,465	166,618	25,260	3,347,343
1823	3,354,022	142,859	43,457	3,540,338
1824	3,675,816	182,696	10,805	3,869,317
1825	3,329,289	161,306	14,678	3,505,273
1826	5,480,283	337,597	37,210	5,855,090
1827	4,401,373	227,970	32,419	4,661,762
1828	4,390,007	233,838	34,487	4,658,332
1829	4,477,214	195,689	31,636	4,704,539
1830	4,770,541	175,486	29,701	4,975,728
1831	4,697,882	165,446	29,467	4,892,795
1832	4,932,337	181,262	57,845	5,171,444
1833	4,664,785	171,053	44,150	4,879,988
1834	4,554,086	155,917	55,346	4,765,349
1835	4,571,580	146,178	47,948	4,765,706
1836	4,425,543	146,785	44,692	4,617,020
1837	4,264,146	120,940	39,379	4,424,465
1838	4,205,742	124,544	37,939	4,368,225
1839	3,877,374	115,243	32,800	4,025,417
1840	3,526,199	91,358	26,853	3,644,410
1841	3,344,922	88,814	30,338	3,464,074
1842	3,099,542	71,927	29,546	3,201,015
1843	3,061,699	71,820	28,438	3,161,957
1844	3,134,350	78,142	30,114	3,242,606
1845	3,431,614	84,478	33,797	3,549,889
1846	4,087,608	114,678	43,044	4,245,330
1847	4,237,406	455,441	210,206	4,903,053
1848	4,103,156	322,543	209,664	4,635,363
1849	4,644,811	368,638	255,476	5,268,925
1850	4,302,513	289,200	213,463	4,805,176
1851	4,320,946	260,184	202,498	4,783,628
1852	4,389,414	265,447	211,397	4,866,258
1853	4,670,051	260,880	211,685	5,142,616
1854	4,699,862	255,580	172,701	5,128,143

It will be observed that there is little variation in the total amount for the three kingdoms, but that the quantities consumed in Scotland, and more especially in Ireland, have been subject to great fluctuations.

It is calculated that, in addition to 24,000,000 gallons of home-made spirit annually consumed in the United Kingdom, there are 4,000,000 gallons of brandy, rum, and geneva. In the year ending January 5, 1853, the quantity of British spirit exported was 323,719 gallons, of which 161,532 were sent to British colonies and possessions, and 162,187 gallons to foreign countries. Of the British possessions, the smallest customer was the island of Mauritius, which only took 5 gallons. The largest quantity was taken by the Australian settlements, *videlicet*, 125,667 gallons. Of foreign countries, Russia, Sweden, Denmark, Prussia, Holland, Belgium, France, Portugal, and Morocco, took each less than 100 gallons. The foreign West Indies are the best customers, taking 156,360 gallons. It is very probable that Australia will soon become the best market for home-made spirit.

In conclusion, the Editor must express his satisfaction at the equalization of the duties on spirits, as regards England and Scotland—a step which was not only wise in itself, as tending to assimilate still further the condition of the two countries, but likewise by removing an inducement to the practice of smuggling, which, although sometimes regarded with leniency, is most demoralizing in its tondency, and ought to be universally reprobated.

ALUM.—*Alun*, French; *Alaun*, German; *Alumen*, Latin. Alum-works existed many centuries ago at Roha, or Roccha, in Mesopotamia, whence the old name of Roch alum is applied to this salt. This is the opinion of LEIBNITZ, who states that *alumen roccæ* was that kind first procured from Rocca, and that the name was subsequently given to every good species of alum. A few are of opinion that alum obtained from alum-stone has been so called to distinguish it from the alum from schists—schist was employed for making alum in the time of AGRICOLA—which usually contains more iron than the former; and others assert that alum acquired the name *rocca*, from the aluminous rocks of Tolfa.

At a later date, alum was manufactured near Smyrna, and in the fifteenth century there were alum factories in the vicinity of Constantinople, where JOHN DI CASTRO learned his art, as will be hereafter noticed.

The inhabitants of Genoa, and other commercial people of Italy, imported alum from the above places into Western Europe for the use of the dyers of red cloth. The stypteria of DIOSCORIDES and the alumen of PLINY included, apparently, a variety of saline matters, of which sulphate of iron—green vitriol—as well as alumina, was probably a constituent part. From the researches of Professor BECKMANN, it appears that alum was discovered by the Asiatics; but at what period, or by what means the discovery was made, is altogether unknown. This salt affords a striking instance of how readily one may be deceived in giving names without proper examination. Alum, as now made, adds BECKMANN, was certainly not known to the Greeks or the Romans; and what the latter called *alumen*, was green vitriol—sulphate of iron—not, however, pure, but such as forms in mines. To those who know how deficient the ancients were in the knowledge of salts, and of mineralogy in general, this assertion will appear highly probable. **Pereira** remarks that **Geber**, who is supposed to have lived in the eighth century, was conversant with alum, and described the method of burning it; and it is probable that even **Pliny** was acquainted with it. It would seem, however, that he confounded alum with sulphate of iron, or a very impure compound, for, when speaking of some substance resembling plumose alum, he says it gave with the juice of the pomegranate a black color, at once a proof that the sulphate of iron was not separated from it. Alum and green vitriol are salts having some resemblance; they contain the same acid—sulphuric—have strong styptic properties; and are not only found collaterally, but frequently form efflorescences on the same minerals.

By alum is universally understood a double sulphate of alumina and potassa, which was the first known and used in the arts; modern science has discovered, however, that this compound does not exclusively engross the term, but that the latter is equally applicable to a series of bodies in which either the sesquisulphate of alumina, or sulphate of potassa, or both, are replaced by other sulphates of similar atomic composition. Notwithstanding that the whole mineral portion of the double salt is changed, yet every one of the class assumes the same crystalline form, and is associated with the same number of atoms of crystalline water. To this peculiarity of different bodies assuming the same external appearance when their atomic constitution is analogous, the term *isomorphism* has been applied. These alums are—

Name.	Formula.
Potassa alum,	$K O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Soda alum,	$Na O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Lithia alum,	$Li O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Ammonia alum,	$N H_4 O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Manganous-magnesia alum,	$\left.\begin{matrix} Mn O \\ Mg O \end{matrix}\right\\} H O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Ferrous alum,	$Fe O, S O_3 + Al_2 O_3, 3 S O_3 + 24$ aq.
Ferric-potassa alum,	$K O, S O_3 + Fe_2 O_3, 3 S O_3 + 24$ aq.
Ferric-ammonia alum,	$N H_4 O, S O_3 + Fe_2 O_3, 3 S O_3 + 24$ aq.
Manganic alum,	$K O, S O_3 + Mn_2 O_3, 3 S O_3 + 24$ aq.
Chromic alum,	$K O, S O_3 + Cr_2 O_3, 3 S O_3 + 24$ aq.

It thus appears that the term alum is applied scientifically and collectively to a great number of double salts, composed of very different proximate elements, arranged, however, in the same manner; that alums are sometimes formed, in which the acid is sulphuric—$S O_3$; in other varieties chromic—$Cr O_3$; some containing potassa—$K O$; others soda—$Na O$, and others again oxide of ammonium—$N H_4 O$; and as the second base, either sesquioxide of iron—$Fe_2 O_3$, sesquioxide of aluminum—$Al_2 O_3$, or sesquioxide of chromium—$Cr_2 O_3$. These different bases and acids possess the power of replacing each other in variable proportions, or several of them may take part in the formation of one and the same crystal of alum, but in every case the alum will contain twenty-four equivalents of water.

Mangano-magnesian alum, and ferrous alum, are not of the regular crystalline form of the others, and, therefore, are not to be viewed as true alums, though their analogous composition to the other alums is the reason why they have been classed here. The name alum is applied, conformably with the preceding feature of the class, to all compound salts whose formula is $R O, S O_3 + R_2 O_3 3 S O_3 + 24$ aq., the letter R being indicative of any metal.

Alum, like saltpetre and carbonate of soda, occurs native, as an effloresced salt in volcanic districts, in the form of a white floccular covering, produced by the action of sulphuric acid vapors upon lava and trachyte—substances containing alumina and potassa—in a similar manner to that by which artificial alum is obtained. In this form it occurs in Auvergne, in the South of France, in Sicily, and the volcanic islands on its Northern coast, but more particularly in the neighborhood of Naples, in the Grotta di Alume—on Capo Miseno—and in the Solfatara.

The effloresced salt is collected in these localities, dissolved in water, and allowed to deposit the insoluble matters by standing. The clear solution affords on evaporation an impure alum, which is re-crystallized, and brought into commerce as a very pure product. No fuel is used for the evaporation but the natural volcanic heat of the soil, rising to 104° Fahr., in which the leaden pans are embedded. Native alum forms, however, a very small portion of that which is consumed in Europe. Dr. **Dieffenbach**, in his account of a voyage to New Zealand, makes mention of a remarkable lake, the water of which contained alum in solution.

The following is the composition of some of these natural alums:—

Constituents.	From Rio Saldanha, Andes.	Soda alum from South America.		Ammonia alum from Tschermig.		
	Thomson.	Thomson.	Gruner.	Pfaff.	Lampadius.	Stromeyer.
Sulphuric acid,	35·872	37·7	33·682	36·00	38·58	36·065
Alumina,	14·645	12·4	10·750	12·14	12·34	11·602
Soda,	2·262	7·5	—	—	—	—
Silica,	0·100	—	—	—	—	—
Lime,	—	—	—	—	—	—
Protoxide of iron,	—	—	3·619	—	—	—
Sesquioxide of iron,	0·500	—	—	0·20	—	0·115
Ammonia,	—	—	—	6·58	4·12	3·721
Water,	46·375	42·4	51·000	45·00	44·96	48·390
	99·754	100·0	99·051	99·92	100·00	99·893

MANGANESE AND MAGNESIA ALUMS.

Constituents.	Algoa Bay, South Africa.	Bosjesman's River, South Africa.	Iquique, South America.
	Apjohn.	Stromeyer.	Hayes.
Sulphuric acid,........	32·79	36·770	36·332
Alumina, ...	10·65	11·515	12·130
Magnesia, ...	—	3·690	4·682
Protoxide of manganese,	7·33	2·617	0·430
Protoxide of iron,......	—	—	
Lime, ...	—	—	0·126
Sulphate of magnesia,..	1·08	—	—
Chloride of potassium,..	—	0·205	—
Hydrochloric acid,....	—	—	0·604
Water, ...	48·15	45·739	45·450
	100·00	100·536	99·754

Drs. RICHARDSON and RONALDS consider the alums analysed by APJOHN and STROMEYER, identical; they cannot be looked upon as chemical compounds, as no two analyses agree, and *in situ* they are much mixed with efflorescent salts. The manganese alum is used by the natives for dressing skins.

In the following table is a number of analyses of various specimens of iron alum—ferrous alum of the formula $Fe\,O\,S\,O_3,\ Al_2\,O_3\,3\,S\,O_3. + 24$ aq. above mentioned—found in different localities. These kinds of natural alums are more abundant in coal mines, where iron pyrites and shale are superposed on the coals, and are often very regularly and beautifully crystallized. They are not, indeed, sufficiently pure to agree exactly with the foregoing formula, some of them containing potash, soda, magnesia, sand, or one or more of these substances, but still it will be seen from the table that their characteristic composition is nearly expressed by it:—

IRON ALUMS.

Constituents.	Unknown.	Hurlet.	Morsfeld.	Iceland	Puzzuoli.		Hurlet.
	Berthier.	Phillips.	Rammelsberg.	Forchhammer.	Dufuroy.	Alich.	
Sulphuric acid,...........	34·4	30·9	36·025	35·16	45·67	48·32	.... 35·950
Protoxide of iron,.........	12·0	20·7	9·367	4·57	28·69	11·60	.... —
Sesquioxide of iron,.......	—	—	—	1·23	—	17·65	.... 18·236
Alumina,.................	8·8	5·2	10·914	11·22	3·27	2·20	.... —
Potash,...	—	—	0·434	—	5·47	4·04	Ammonia,...... 3·653
Soda,...................	—	—	—	—	—	0·25	.... —
Magnesia,................	0·8	—	0·235	2·19	—	—	....
Sand, ...	—	—	—	—	0·46	—	Impurities,....... 3·500
Water,...................	44·0	43·2	43·025	45·63	15·77	15·94	.... 38·661
	100·0	100·0	100·000	100·00	99·33	100·00	.... 100·000

From what has already been stated, it will be seen that alums, of whatever elements they may be composed, are not merely a combination of sulphuric acid and alumina—$Al_2\,O_3\,3\,S\,O_3$—but have in addition another sulphate, either of potassa, soda, or ammonia. The alum of this country usually contains potassa; that of France, ammonia, or potassa and ammonia—hence the name potassa-alum, ammonia-alum, soda-alum. The Greeks or Romans mention no other than natural alum; but alum is rarely produced spontaneously in the earth, and many most accurate mineralogists deny even the existence of native alum. Although it is not found in abundance, still there can be no question as to its occasional occurrence as an efflorescence of stones, and in certain mineral waters. Crystals of real alum are occasionally formed in minerals abounding in an eminent degree with aluminous particles, when they have been exposed a sufficient time to the air and rain; but even then they are so small, and so much scattered, that it requires a good lens and an expert observer to discover them. Basic alum exists native in a stone near Civita Vecchia, which consists of—

Sulphate of potassa,.....................	19·72
Sulphate of alumina-basic,.................	61·99
Water,..................................	18·29
	100·00

This mineral, when treated with a sufficient quantity of sulphuric acid dissolves, and is converted into the crystallizable alum of commerce.

The true composition of alum has not long been understood. VAUQUELIN and CHAPTAL appear to have been the first chemists who ascertained, by decisive experiments, that alum was composed of sulphuric acid, alumina, and potassa, ammonia, or soda, united.

The celebrity acquired by alum among the ancients, as a substance extremely useful in dyeing and medicine, was entirely forgotten at the time the alum of the moderns became known; but it was again revived when it was discovered that real alum could be extracted from minerals containing sulphur compounds, or that where the latter are found there are generally minerals abounding with it. In many of these places, alum-works have, in the course of time, been erected; and, as BECKMANN ingeniously remarks, this circumstance has served, in some measure, to strengthen the opinion that the alum of the ancients and of the moderns is synonymous; because, where the former was found, the latter has since been procured by a chemical process. Some historians of the fifteenth century even speak of the alum-works as if the manufacture of this salt had only been revived in Europe.

Alum owes its high estimation to its beneficial use in the art of dyeing, in which it is employed as a mordant. The Italians procured their first alum from the Levant, along with other materials; but when these countries were taken by the Turks, it grieved the Christians to be compelled to purchase these necessary materials from the common enemy. In due time the Italians became acquainted with the art of boiling alum, and when they at length discovered aluminous minerals in their own soil, these were soon brought into use, which caused the Turks to abandon many of their alum-works. The modern alum was, in the beginning, distinguished from the ancient by the denomination of *rocca*.

DUCAS describes very minutely the alum-work at Foya Nova, near Smyrna; but that work has been long since abandoned. Drs. FRANCIS and GRIFFITH state, that in Phocis, lying close to Ionia, there is a mountain rich in aluminous mineral. The stones found at the summit are first calcined in the fire, and then reduced to powder by throwing them into water. The moist mass is put into a kettle, a little more water added, and the whole having been made to boil, the powder is lixiviated, the thick part which falls to the bottom in a cake is preserved, and the hard and earthy portions are discarded. The cake is afterwards allowed to dissolve in vessels for four days, at the end of which the alum is found in crystals around their edges, and their bottoms are also covered with the salt; the remaining liquor is poured into a kettle, diluted with water, and more powder added, then boiled as before, and put into proper vessels to crystallize. The alum obtained in this manner is preserved as an article very necessary for dyers. Captains of ships bound from the Levant to Europe, consider alum as a very convenient and useful cargo for their vessels.

The alum-works near Civita Vecchia are, by Italian historians, asserted to have been the first in Europe—they are the oldest carried on at present. They were founded by JOHN DI CASTRO, who has been already mentioned as learning the process near Constantinople. He was there at the time the superb city fell into the hands of the Turks, trading in Italian cloths and dye-stuffs; after this he returned to his own country, and having found, in the neighborhood of Tolfa, a plant which he had observed growing abundantly in the aluminous districts of Asia, he conjectured that the virgin soil might also contain the same salt, and the astringency of its taste proved he was correct. On this discovery, factories were immediately erected, the produce of which was vended to the Venetians, the Florentines, and the Genoese. The stones were first calcined, a large quantity of water was then thrown over them, and when they were entirely dissolved, the lie was boiled in great leaden caldrons; after which, it was run into wooden vats and allowed to evaporate spontaneously; the result was alum of the most perfect kind. Pope PIUS the Second employed more than eight hundred persons in preparing it. BECKMANN continues—The plant which first induced CASTRO to search for alum was the prickly evergreen, *Ilex aquifolium*, which in Italy is still considered as an indication that the regions where it thrives abound with alum. This shrub, or holly, is, however, frequently found growing where there is not the slightest trace of this salt.

It appears, from all that can be learned, that the art of boiling alum was first understood in Italy, but not previous to 1548. The great revenue which the Apostolic Chamber derived from alum induced many to seek aluminous minerals, and factories were built wherever such were found. The Pope, however, understood his own interest so well, that he never rested until he had caused all the works erected in the other territories to be discontinued, by which he alone remained master of the prize. Like all tyrants, he endeavored, by every possible means, to prevent foreigners acquiring any knowledge of the art. His commerce increased more and more, and he instructed his menials to demand exorbitant prices for the salt, so that foreigners purchased from the Spaniards and Turks. The ban of excommunication was threatened in case any one should be so unchristian as to purchase alum from the infidels, while every person was at liberty to make what bargain he liked with the Bishop of Rome for this commodity! But these measures, like all those founded on the simplicity of others, could not long be endured; as soon as men became more enlightened, they saw through the duplicity of the head of the Romish Church, and discovered the selfishness of his bulls. Alum-works soon appeared in Germany, and, in 1554, at Oberkaufungen, in Hesse, a factory was in full operation. In England, the first alum-work was erected at Gisborough, in Yorkshire, where Sir THOMAS CHALONER had an estate. The knight engaged workmen well versed in the Roman alum business, because there was no one in England who then understood its facture. It is said that, as soon as the Pontiff heard this, he endeavored to recall the renegades by threats and anathemas. These, however, were of no avail, and did no injury to the heretics; in a short time the manufactory was most flourishing, and several more of the same kind were soon after established. PENNANT, in his Scotch Tour, has the following:—The alum-works in this country are of some antiquity; they were first established in the reign of Queen ELIZABETH, by Sir THOMAS CHALONER, who, observing the trees tinged with an unusual color, made him suspicious of its being owing to some mineral in the neighborhood. He ascertained that the strata abounded with an aluminous salt. At that time the English, being strangers to the method of managing it, there is a tradition that Sir THOMAS was obliged to seduce some workmen from the Pope's alum-works, then the greatest in Europe. If one may judge, from the curse which his Holiness thundered out against the knight and his fugitives, he certainly was not a little enraged; for he cursed without varying a tittle from that most comprehensive of imprecations left us by ERNULPHUS. The first pits were near Gisborough, the seat of the CHALONERS, who still flourish there, notwithstanding the Bishop of Rome's interdictions.

Before entering minutely into the fabrication of alum, it will be proper to state how and where the salt is obtained. The greater portion of the alum in this country is manufactured from alum-slate—a bituminous schist containing sulphide of iron diffused in very fine particles throughout its mass; it has a bluish or greenish-black color, and eliminates sulphurous acid when burned, acquiring thereby an aluminous taste. Many of the alum-slates crumble to pieces, or suffer disintegration, on exposure to the air; their sulphur becomes gradually converted into sulphuric acid, by absorbing oxygen from the atmosphere, while, simultaneously, the iron is sesquioxidized, and having in this state a very feeble affinity for the sulphuric acid, parts with the greater portion to the clay, which is thereby converted into sesquisulphate of alumina, and this, when combined with sulphate of potassa, constitutes the alum of commerce. Alum may be prepared by decomposing clay with sulphuric acid; the decomposition is effected in as complete a manner by calcining pure clay, grinding the adusted mass to powder, and mixing it with about half a per cent. of sulphuric acid. This mixture is then to be heated in a furnace till the mass becomes very thick; afterwards left to repose for a month or more, and then affused with water, to wash out the sulphate of alumina. The addition of a potassa salt converts it into alum.

GRAHAM states that the old method of making alum is still largely practised in this country:—A series of beds occur low in many of the coal measures, which contain much bisulphide of iron. One of these, known as alum slate, is a siliceous clay, containing a considerable portion of coaly matter, and of the metallic sulphide in a state of minute division. When this mineral is exposed to air and moisture, it soon exfoliates, from the formation of sulphate of iron, the bisulphide of iron absorbing oxygen like a pyrophorus. The excess of sulphuric acid formed, attacks the other bases present, of which the most considerable is alumina. Aluminous schists often require to be moderately calcined or roasted, before they undergo this change in the atmosphere. The mineral being lixiviated, after a sufficient exposure, affords a solution of sulphate of alumina and protosulphate of iron, from which the latter salt is separated by crystallization. The subsequent addition of sulphate of potassa to the liquor, causes the formation of alum; the chloride of potassium answers the same purpose, and has the advantage over the sulphate, that it converts the remaining sulphates of iron into chlorides, which are very soluble, and from which the alum is most easily separated by crystallization.

Alum requires about eighteen parts of cold, and less than one part of boiling water to dissolve it, and crystallizes very readily in large regular octahedrons, of which the apices are always more or less cut off. Its taste is sweetish, and very astringent. It is an acid salt, reddens vegetal blues, and dissolves metals with evolution of hydrogen; it slightly effloresces in the air, and at a gentle heat suffers the aqueous fusion. Its water of crystallization amounts to 45·5 per cent. of its weight, or twenty-four atoms. The fused salt, in losing this water, becomes viscid, and intumesces, leaving calcined or burnt alum, which is sometimes used as a corrosive.

The octahedral crystals of potassa alum consist of sulphuric acid, alumina, potassa, and water, in the annexed proportions:—

	Atomic weight.		Centesimally represented.
1 Eq. Sesquisulphate of alumina,.........	172	....	36·21
1 Eq. Sulphate of potassa,................	87	....	18·31
24 Eq. Water,.............................	216	....	45·48
1 Eq. Crystallized potassa alum,.........	475		100·00

Or of—

1 Eq. Alumina,............................	52	....	10·94
1 Eq. Potassa,............................	47	....	9·89
4 Eq. Sulphuric acid,.....................	160	....	33·68
24 Eq. Water,.............................	216	....	45·49
1 Eq. Crystallized alum,.................	475		100·00

Formula,...... $Al_2\,O_3\,3\,S\,O_3,\ K\,O,\ S\,O_3 + 24$ aq.

The solubility of this salt is, according to **POGGIALE**, as follows:—

100 parts of water	at	32°,	dissolve	3·29	parts of alum.
"	"	50	"	9·52	"
"	"	86	"	22·00	"
"	"	140	"	31·00	"
"	"	158	"	90·00	"
"	"	212	"	357·00	"

At a white heat, all the sulphuric acid in combination with the alumina, and the water of crystallization, pass off, leaving a mixture of the earth and sulphate of potassa. When crystals of alum are heated in a retort, an acid solution—spirit of alum, according to the old chemists—distils over and collects in the receiver. Potassa alum, on being ignited with charcoal, is converted into a pyrophorus.

Alum, when heated with alkaline chlorides, liberates hydrochloric acid; again, if a concentrated solution of this salt is boiled with chloride of sodium or potassium, the same acid is given off, and a sparingly soluble basic alum precipitated. **RICHTER** states that a solution containing alum, chloride of sodium, and nitrate of soda, is a solvent for gold.

When alum is dissolved in twenty parts of water, and ammonia dropped slowly into the solution till the liquid is nearly saturated, a bulky white precipitate appears, which, when thoroughly edulcorated with distilled water, is pure alumina. If dried and weighed, it will be found to be 10·82 per cent. of the weight of the alum taken. If this earth, while moist, be dissolved in dilute sulphuric acid, it will constitute, when as neutral as possible, the sulphate of alumina, which requires only two parts of cold water for solution. If this solution be now decomposed by pouring into it liquid ammonia, there appears an insoluble white powder—subsulphate of alumina or basic alum. It contains three times as much earth as the neutral sulphate. However, by adding a strong solution of sulphate of potassa to that of the neutral sulphate, a white powder will fall, which is true alum. When recently-precipitated alumina is boiled in a solution of alum, a portion of the earth enters into combination with the salt, constituting the insoluble compound which falls as a white amorphous powder: the same combination occurs if a boiling solution of alum be decomposed by potassa.

These experimental facts develop the principles of the manufacture of alum, which is prosecuted under various modifications for its important uses in the chemical arts.

MANUFACTURE OF ALUM.—Two alums, only, are applied in the arts; these are composed of sesquisulphate of alumina, in combination with sulphate of potassa, or sulphate of ammonia, or both, as given in the annexed formulæ:—

$$K\,O,\quad S\,O_3 + Al_2\,O_3,\ 3\,S\,O_3 + 24\text{ aq.}$$
$$Am\,O,\quad S\,O_3 + Al_2\,O_3,\ 3\,S\,O_3 + 24\text{ aq.}$$
$$\left.\begin{array}{l}K\,O\\ Am\,O\end{array}\right\}\ S\,O_3 + Al_2\,O_3,\ 3\,S\,O_3 + 24\text{ aq.}$$

The first of these, potassa alum, is simply called alum amongst practical men, whilst the second variety is distinguished by the name of *ammonia alum.* The latter is easily distinguished from the former by its giving out the odor of ammonia when triturated with quicklime. The potassa alum is preferred by turkey-red dyers; but both are used by dyers and calico-printers solely for their alumina, and in this particular they are accounted nearly of equal value; the other constituents being almost useless. The possibility, however, of producing a cheap and pure salt of alumina in large quantities, is dependent on the property alum possesses, of separating from its concentrated solutions in large, well-defined crystals; the purity of the alumina in this salt, and which is necessary in the applications of alum, enables the purchaser to pay for the sulphuric acid, water, and alkali, although they are useless, except for effecting the crystallization. Sulphate of alumina is with great difficulty separated from many other extraneous salts that accompany it in the manufacture, particularly from sulphate of iron, whilst alum, from the ease with which it dissolves in hot water, and its sparing solubility in cold, is readily separable from any adventitious substances.

Production of Alum from Alum Stone.—Alum is obtained in much larger quantity from alum rock, a formation of volcanic origin, than from any other source. This is a massive, granular, only partially crystalline, transparent, and not homogeneous rock, which frequently encloses quartz, sometimes iron pyrites, and manganese ore. Its color is yellowish, passing into green, grey, red, or brown. The pure mineral alum stone, *alunite*, sometimes occurs in it in distinct crystals, which have been found to consist of a basic sulphate of alumina, with sulphate of potassa, and is, therefore, a basic alum, or, more probably, a combination of neutral sulphate of alumina and potassa, with hydrate of alumina, $K O, S O_3 + Al_2 O_3, 3 S O_3 + 2 Al_2 O_3, 3 H O$.—*Rammelsberg.* It differs, therefore, from alum, in containing an excess of alumina. Alum rock is of the same nature—a massive alunite, but of a less pure character; it is found at Tolfa, near Civita-Vecchia, in the Papal States; at Montione, in the dukedom of Piombino; in the Comitats, Beregh, and Zemplin, in Hungary; at Mont d'Or, in France; and in the Greek islands, Milo and Nipoglio; but is not of very common occurrence in other places. The analyses of this rock have yielded the following results:—

	From Tolfa, by Klaproth.	From Beregszaz, by Klaproth.	From Moutione, by Descotil.	From Mont d'Or. by Cordier.
Silica,..................	56·5	62·3	—	28·4
Alumina,...............	19·0	17·5	40·0	31·8
Sulphuric acid,.........	16·5	12·5	35·6	27·0
Potassa,................	4·0	1·0	13·8	5·8
Water,.................	3·0	5·0	10·0	3·7
Sesquioxide of iron,....	—	—	—	1·4
Loss,.................	1·0	1·7	0·6	1·9
	100·0	100·0	100·0	100·0

It will be seen from these analyses, that, overlooking the silica, there is chiefly a deficiency of potassa, and also of sulphuric acid, in the rock, for the formation of alum; but, in the mineral from Tolfa, for instance, there is about three per cent. of sulphuric acid, and fourteen per cent. of alumina, more than are requisite to form alum with the four per cent. of potassa. The alum stone from Beregszaz also contains an excess of nine per cent. of acid, and sixteen per cent. of earth; that from d'Or, six per cent. of acid, and twenty-five per cent. of alumina. At Tolfa, where the alum stone comes to the surface, a quantity of alum is produced proportionate to the amount of potassa in the rock, and the remainder, particularly the excess of alumina, is separated. This is effected by burning the stones in heaps, or furnaces, similar to those used in preparing gypsum—Fig. 86—particular care being taken that the temperature does not rise too high.

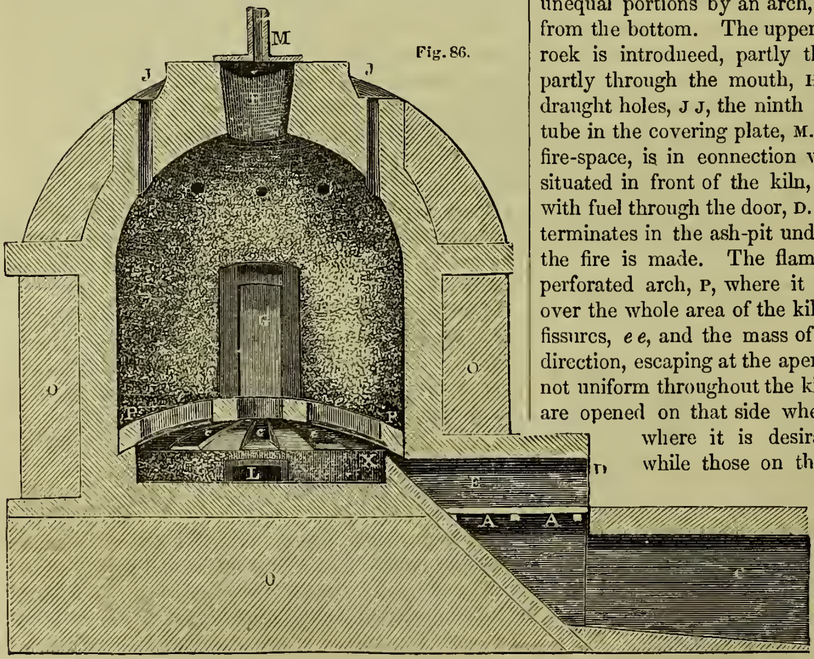


Fig. 86.

The inner chamber of this kiln is divided into two unequal portions by an arch, P P, situated about a foot from the bottom. The upper part, into which the alum rock is introduced, partly through the door, G, and partly through the mouth, H, is provided with eight draught holes, J J, the ninth hole being formed by the tube in the covering plate, M. The lower chamber, or fire-space, is in connection with the fire, E, which is situated in front of the kiln, and which is replenished with fuel through the door, D. The draught-channel, C, terminates in the ash-pit under the grate, A, on which the fire is made. The flame enters at X, below the perforated arch, P, where it is uniformly disseminated over the whole area of the kiln, and passes through the fissures, *e e*, and the mass of materials, in an upward direction, escaping at the apertures, J J. If the heat is not uniform throughout the kiln, the draught-holes, J J, are opened on that side where it is least intense, and where it is desirable to lead the flame, while those on the other side are closed. The aperture, L, is used for clearing the fire-chamber, and is closed, as well as G and H, during the firing. Particular attention is given to the maintenance of a proper temperature. O O represent the exterior walls of the kiln, made of non-conducting materials to secure the retention of the heat.

At a red heat, sulphate of alumina is decomposed, yielding, partly anhydrous sulphuric acid, and partly oxygen and sulphurous acid. As soon as these vapors appear, the burning is stopped, and the mass is transferred to walled cisterns, where it is repeatedly moistened with water, which collects below, and is allowed to disintegrate for three or four months, at the expiration of which period it is converted into a soft mud, tasting perceptibly of alum, which may then be dissolved out with water. If the alum stone contained an excess of hydrate of alumina, this would infallibly react upon the alum, and form with it a similar but insoluble compound, containing basic sulphate of alumina—the burning expels the water from the hydrate of alumina, and thus renders it chemically inactive; the excess of alumina is thus separated from the compound, which then yields an alum soluble in water. During the evaporation—until the specific gravity is 1·114 at 113° Fahr.—the lie still holds a fine ferruginous rose-red powder in suspension, which feebly colors the crystals, but is left when these are redissolved. The crystals contain potassa, but no ammonia, and are highly prized in commerce, under the name of *Roman alum.*

PRODUCTION FROM ALUM ORE.—The production of alum from alum shale and alum earth is systematically carried out or divided into three distinct operations: the production of sulphate of alumina; the addition of sulphate, or chloride, of the alkali to the concentrated cold solution of the former, in which operation the difficultly soluble alum precipitates in the form of powder, and is thus separated from the foreign salts; and, lastly, the purification of the alum flour by recrystallization.

Alum shale is a kind of clay slate impregnated with sulphide of iron and bituminous matters—a member, therefore, of the younger transition series of rocks—allied to real clay slate by its firmness, appearance, slaty structure, and great extent. Although it is not so abundantly disseminated as other species of rocks and minerals, it forms, nevertheless, beds of considerable extent in many localities, particularly in the Scandinavian peninsula in Bohemia; in the Hartz, in Upper Bavaria; in Voigtland, in the mountainous districts of the Lower Rhine; in England, near Whitby; in Scotland, at Hurlet and Campsie, near Glasgow; in the Uralian Mountains. It may be also met with in many other districts, but not in sufficient quantity to be available for practical purposes.

The following analyses show the composition of the rocks:—

ALUM SHALE FROM SIEHDA, BY LAMPADIUS.

Sesquisulphate of alumina,	2·68
Potassa alum,	0·47
Sulphate of iron,	0·95
Sulphate of lime,	1·70
Silica,	10·32
Alumina,	9·21
Magnesia,	traces
Sesquioxide of iron,	2·30
Oxide of manganese,	0·31
Sulphur,	7·13
Water,	33·90
Carbon, *et cetera*,	31·03
	100·00

ALUM SHALES, BY G. KERSTEN.

	Hermannsschachte.	Gluckaufgang.	Blucherschachte.
Carbonaceous matters,	41·10	27·92	34·20
Silica,	44·02	51·32	50·21
Sesquioxide of iron,	6·23	8·40	0·42
Alumina,	5·60	7·62	5·21
Magnesia,	0·32	0·26	0·53
Oxide of manganese,	0·12	traces	traces
Sulphur,	1·25	2·89	1·72
Sulphate of lime,	traces	traces	traces
Loss,	1·36	1·59	7·71
	100·00	100·00	100·00

ALUM SHALES, BY ERDMANN.

Soluble in acid.	Garnsdorff.		Wezelstein.	
Sulphide of iron,	7·533		10·166	
Silica,	0·060		0·100	
Sesquioxide of iron,	0·966		2·466	
Alumina,	1·833		3·166	
Lime,	0·400		1·000	
Magnesia,	trace		1·022	
		10·792		17·920
Insoluble in acid.				
Silica,	50·066		52·200	
Alumina,	8·900		17·900	
Sesquioxide of iron,	1·300		3·366	
Magnesia,	1·000		1·133	
Lime,	trace		trace	
Coal,	22·833		0·803	
		84·099		75·402
Loss,		5·109		6·678
		100·000		100·000

Subjoined is the composition of several shales which are sometimes used in the manufacture of alum:—

	Locality unknown. D'Aubisson.	Dunmeniss, Dovonshire. Stokes.	Gaggenan, Baden. Holtzmann.	Niedesselten, Nassau. Wimph.	Goslar, Hartz. Frick.	Brenndaff, N. Coblentz. Frick.	Lehsten, Thuringerwald. Frick.	Prague. Plerschl.
Silica,	48·6	59·4	64·34	79·17	60·03	62·83	64·57	67·50
Alumina,	23·5	17·4	23·90	10·42	14·91	17·11	17·30	15·89
Sesquioxide of iron,	11·3	11·6	9·70	6·27	8·94	8·23	7·46	5·85
Oxide of manganese,	0·5	—	—	—	—	—	—	0·08
Lime,	—	2·1	—	—	2·08	0·83	1·16	2·24
Magnesia,	1·6	2·2	—	—	4·22	1·90	2·60	3·67
Potash,	4·7	—	—	—	3·87	4·17	1·99	1·23
Soda,	—	—	—	—	—	—	—	2·11
Strontia,	—	—	—	—	—	—	—	0·30
Oxide of copper,	—	—	—	—	0·28	0·27	0·30	—
Fluoride of calcium,	—	—	—	—	—	—	—	} 1·13
Phosphoric acid,	—	—	—	—	—	—	—	
Sulphur,	0·1	—	—	—	—	—	—	—
Carbon,	0·3	—	—	—	—	—	—	—
Carbonic acid,	—	—	—	—	} 5·67	4·66	4·62	—
Water,	7·6	6·4	2·22	2·78				—
Loss,	1·8	0·9	—	1·36	—	—	—	—
	100·0	100·0	100·16	100·00	100·00	100·00	100·00	100·00

The annexed is the composition of some shales from Whitby, in Yorkshire, and Campsie, near Glasgow:—

	Whitby. Richardson.			Campsie.			
	Top rock.	Bottom rock.		Top rock.	Top rock.		Bottom rock.
Sulphide of iron,	4·20	8·50	Sulphur,	22·36	23·44	Pyrites,	9·63
			Iron,	18·16	15·04		
Silica,	52·25	51·16		15·40	15·40		0·47
Protox. of iron,	8·49	6·11		—	—		2·18
Alumina,	18·75	18·30		11·35	11·64		18·91
Lime,	1·25	2·15		1·40	2·22		0·40
Magnesia,	0·91	0·90		0·50	·32		2·17
Oxide of manganese,	traces	traces		0·15	—		0 55
Sulphuric acid,	1·37	2·50		—	—		0·05
Potassa,	0·13	traces		0·90	—		1·26
Soda,	0·20	traces		—	—		0·21
Chlorine,	traces	traces		—	—		—
Coal,	4·97	8·29	Carbon and Loss,	29·78	Carbon, 28·80		8·51
Water,	2·68	2·00		—	—		8·54
Loss,	4·80	8·09		—	3·13		0·59
	100·00	100·00		100·00	99·99		100·00

The Campsie alum ores, especially the upper, contain a large excess of pyrites, yielding of course more sulphuric acid than the alumina can take up, while the lower have a considerable excess of alumina; it is, therefore, the object of the manufacturers of alum to mix these ores in such a manner that the different ingredients may be made available as far as possible.

The composition of the residue from the Campsie ores, after calcination and washing out the alum, is:—

Silica,	38·40
Alumina,	12·70
Sesquioxide of iron,	20·80
Oxide of manganese,	traces
Lime,	2·07
Magnesia,	2·00
Potassa,	1·00
Sulphuric acid,	10·76
Water,	12·27
	100·00

It is well known that alum earth belongs to the more recent deposits, occurring below the first strata of the tertiary coal formation, which are of a later period than the chalk. It is a massive but soft pulverizable mass, stratified, but not slaty, and of a dark-brown color; it occupies basins of variable dimensions, according to the position of the neighboring rocks. Very large deposits of this formation occur in the valley of the Oder, and are worked at Freienwalde and Muskau. It is no uncommon phenomenon, in the coal formations, for the clay and coal strata to permeate each other in those localities where they meet. These deposits, which frequently cover the coal formation, and are, at other parts, in alternate layers with the coal, play the part of alum ores, and may be worked for the production of alum, when they contain a sufficient quantity of sulphide of iron, which is often the case. To this class belong the Scotch ores. In Upper Silesia it is even found profitable to make the refuse coal, or *brees*, which cannot well be used as fuel, subordinate to the production of alum; these coals leave an aluminous ash, and those which are rich in iron pyrites are only distinguished from a real alum ore by their large excess of combustible matter, and which, in this case, cannot be turned to account.

Iron pyrites, or the bisulphide of iron—$Fe\,S_2$—is quite as indispensable to the production of alum as alumina itself. This compound is formed by the decomposition of protosulphate of iron—$Fe\,O,\ S\,O_3$—held in solution in water by the fossil coal. Green vitriol, or protosulphate of iron, is deprived of oxygen by an organic substance being retained for a length of time in contact with it, and becomes reduced to sulphide of iron. The sulphide is disseminated through the alum ores, partly in the well-known brilliant yellow crystals, or crystalline deposits, but chiefly in a very fine state of division, as a dull, black powder, somewhat resembling the mass obtained by precipitating a salt of iron by sulphide of ammonium. Hence, inasmuch as it was not perceptible to the eye, its presence has not only been overlooked in the following analyses, but actually denied:—

	Alum earth.	
	From Freienwalde. Klaproth.	From Putzberg. Bergmann.
Alumina,	16·00	10·90
Silica,	40·00	45·40
Magnesia,	0·25	—
Sulphur,	2·85	3·94
Carbon,	19·45	5·95
Protoxide of iron,	6·40	5·50
" manganese.	—	0·60
Protosulphate of iron,	1·80	5·73
Sulphate of alumina,	—	1·20
" lime,	1·50	1·71
" potassa,	0·50	1·75
Chloride of potassium,	0·50	0·35
Sulphuric acid,	—	0·47
Water,	10·75	16 60
	100·00	100·00

The sulphur is in combination with the iron, and not, as was formerly supposed, in the free state, or as sulphide of carbon. Although the constituents of alum earth are nearly the same in specimens taken from other localities, the proportions are nevertheless variable, as might have been expected from the mode in which the deposits are formed; so great, indeed, is the difference in this respect, that the examples given above can hardly be viewed as a fair average of these compounds. Pyrites and alum ores owe the property of being rapidly decomposed under the influence of atmospheric air to the fine state of division of the bisulphide, and probably, also, to the occasional presence of the protosulphide of iron. Massive crystalline pyrites is very slowly decomposed under the same circumstances. The decomposition is occasioned by seven equivalents of oxygen being taken up by the pyrites—$Fe\,S_2$—which convert it into protosulphate of iron and sulphuric acid—$Fe\,O,\ S\,O_3$, and $S\,O_3$. This combination of the oxygen with the iron and sulphur, is induced by contact of oxygen, and a spontaneous rise of temperature which results from the chemical union; when the latter becomes more developed, it converts the sulphide of iron, as by roasting, into protosulphide and sulphur, which immediately burn, the former being resolved into protosulphate of iron, and the latter into sulphurous acid, which is absorbed by the alumina. The sulphite of alumina thus formed is easily changed, by absorption of atmospheric oxygen, into sulphate of alumina; or, as RICHARDSON justly remarks, what is more likely, by reducing the sesquisulphate to the state of sulphate of the protoxide. The alum ore, when first taken from the ridges—calcined heaps—and covered with water, which is removed after a short interval, will be found to have yielded little sulphate of alumina to the solution, but a great deal of sesquisulphate of iron; while, after being allowed to remain for some time over the ore, the solution will be found to contain much sulphate of alumina and protosulphate of iron: alum-makers know that the first washes are not those which afford the most alum, unless the ore has been permitted to remain in the steeps for a length of time; they are also aware that more alum is procured by adding to the lie a portion of *mothers*, which are very rich in sesquisulphate of iron, than is obtained by pure water, *per se*.

The sulphides of iron are, therefore, available to the production of alum merely by affording the necessary amount of sulphuric acid to unite with the alumina; besides the acid produced by the second portion of sulphur in the bisulphide, another portion is combined with alumina by the decomposition of the green vitriol, the protoxide of iron in which is speedily converted into sesquioxide by the oxygen of the air, and is precipitated in the form of a basic salt. Potassa, which is never altogether wanting in the alum ores, gives rise in a similar manner to the liberation of sulphuric acid by the production of basic sulphate of potassa and iron; sesquisulphate of iron is also decomposed by hydrate of alumina, and sulphate of alumina dissolves, but the greater portion remains insoluble with the basic sulphate of iron.

Lime in the ores is most prejudicial, for this base deprives the sulphate of alumina and sulphate of iron of their sulphuric acid, and entirely puts a stop to the production of alum; ores containing any considerable quantity of lime, cannot, consequently, be used in this manufacture. Gypsum, however, is always found in the crude lies. Magnesia is no less deleterious to the formation of alum, but the sulphate of magnesia—Epsom salt—thus produced, is not totally valueless. In some of the English alum-works, the Epsom salt is a most important object. Fresh alum ores contain no soluble salts of alumina or iron; it is only where air has had access to them, either in the pit or at the surface, that efflorescence in the form of fine needles—feather alum—is observed, and this consists partly of real alum, partly of sulphate of alumina, or of combinations of the latter salt with protoxide of iron, sulphate of magnesia or other salts.

An aluminous sulphate of iron occurred abundantly some years ago in the Hurlet and Campsie wrought-out coal beds, which had the following composition:—

	Berthier.	Phillips.	R. D. Thomson.	R. D. Thomson.
Sulphuric acid,..	34·40	30·90	35·600	28·635
Protoxide of iron,	12·00	20·70	13·560	19·935
Alumina,.......	8·80	5·20	7·127	2·850
Magnesia,......	0·80	—	—	—
Water,.........	44·00	43·20	43·713	48·580
	100·00	100·00	100·000	100·000

The composition of this feather alum, or *hair-salt*, as it is termed in different localities, is shown by the subsequent analyses. The term hair-salt, sometimes given to these natural effloresced bodies, belongs more properly to the sulphate of magnesia often accompanying them.

COMPOSITION OF NATURAL SULPHATE OF ALUMINA—FEATHER ALUM.

	Saldana.	Pasto.	Pyromeni, in Island Milo.	Coquimbo, Chili.	Kolosorak, Bohemia.	Friersdorff, near Bonn.	Potschappel, near Dresden.	Freienwalde.	Ararat.	Andes.	Campsie, Glasgow.
	Columbia.										
Sulphuric acid,........	36·400	35·68	40·31	36·97	35·82	37·380	35·710	35·637	58·58	35·872	40·425
Alumina,.............	16·000	14·98	14·98	14·63	15·57	14·867	12·778	11·227	38·75	14·645	10·482
Sesquioxide of iron,....	0·004	—	—	2·58	—	—	—	—	—	0·500	8·530
Protoxide of iron,......	—	—	—	—	—	2·463	0·667	·718	$\left.\begin{matrix}SO_3\\FeO\end{matrix}\right\}2{\cdot}78$	—	—
Protoxide of manganese,	—	—	—	—	—	—	1·018	0·307	—	—	—
Potassa,..............	—	—	0·26	—	—	0·215	0·324	0·430	—	—	1·172
Soda,.................	—	—	1·13	—	—	—	—	—	—	2·262	—
Lime,.................	0·002	—	—	—	—	0·149	0·640	0·449	—	—	—
Magnesia,.............	0·004	—	0·85	0·14	—	—	0·273	1·912	—	—	—
Hydrochloric acid,......	—	—	0·40	—	—	—	—	—	—	—	—
Silica,................	—	—	1·13	1·37	—	—	—	0·430	—	0·100	—
Water,................	46·600	49·34	40·94	44·64	48·61	45·164	47·022	48·847	—	46·375	36·295
Loss,.............. ..	0·990	—	—	—	—	—	1·568	·043	—	0·246	3·096
	100·000	100·00	100·00	100·33	100·00	100·238	100·000	100·000	100·11	100·000	100·000
	Boussingault.		Hartwell.	H. Rose.					Gobel.	T. Thomson.	

The manufacture of alum from alum schists may be distributed under the six following heads:—

Preparation of the alum slate.
Lixiviation of the ustulated slate.
Evaporation of the lixivium.
Addition of the saline ingredients.
Edulcoration of the aluminous salts.
Crystallization.

Preparation of the Alum Slate.—Roasting or Ustulation.—Some alum slates are of such a nature that, being piled in heaps in the open air, and moistened from time to time, they get spontaneously hot, and by degrees fall into a pulverulent mass, ready to be lixiviated. The greater part, however, require the process of ustulation, from which many advantages are derived. The cohesion of the dense slates is thereby so much impaired, that their disintegration becomes more rapid; the decomposition of the pyrites is quickened by the expulsion of a portion of the sulphur; and the ready-formed sulphate of iron is partly decomposed by the heat, with a transference of its sulphuric acid to the clay, and the production of sulphate of alumina.

Such alum slates as contain too little bitumen, or coal, for the roasting process, must be interstratified with layers of small coal or brushwood. The fuel being kindled, the whole slowly ignites. More rock is piled upon it, until, in some instances, a vast heap of inflamed material, one hundred feet high, and two hundred feet square, is raised, which continues to burn for months. When the heap is fired with brushwood, its ash, yielding potassa, gives rise to the formation of small quantities of alum.

Alum is manufactured at Whitby by the combustion of the schists of the upper lias, which contain a quantity of iron pyrites and bituminous or carbonaceous matter. The temperature being regulated, and water occasionally supplied, decomposition occurs, producing sulphates of alumina, iron, and magnesia—*exempli gratia*—

$$4\,\mathrm{Fe\,S_2} + \mathrm{Al_2\,O_3} + \mathrm{Mg\,O} + \mathrm{O_{28}} = 4\,\mathrm{Fe\,O,\,S\,O_3} + \mathrm{Al_2\,O_3,}\ 3\,\mathrm{S\,O_3} + \mathrm{Mg\,O,\,S\,O_3}.$$

In Rhenish Prussia, especially at Salzweiler, the ustulation is effected spontaneously, by the aid of a stratum of brown coal beneath it, which has continued in a state of incipient and restricted combustion ever since 1660, when it was accidentally ignited.

A clay bottom is well adapted for the erection of a heap, to prevent any of the salts being carried by the moisture into the soil; the heap is also sometimes constructed under a shed. As a general rule, the produce is better the slower and more uniform the heat during the calcination.

The Scotch alum-works are those of Hurlet and Campsie—the former six miles South from Glasgow, the latter about nine miles North of the city, at the foot of the Campsie Hills. Mr. KING, of the Campsie works, is also proprietor of one of the establishments at Hurlet; the other belonging to Messrs. JOHN WILSON and SONS. The two factories at Hurlet embrace an area of eighteen to twenty acres, the greater portion of the space being occupied by the calcining fields. The aluminous shale found in this locality is interstratified between the coal bed and the limestone, and is nearly as dark-colored as the former; it is occasionally found mixed with native crystals of sulphate of iron. After the shale has been exposed to the air for some time, the black color is replaced by a grey, owing to the action of the air causing it to throw out a white efflorescence of alum.

A striking appearance is presented by the alum-field, which is covered throughout with ridges or elongated mounds of the ore for calcination, or already calcined, and these assume a reddish-brown hue from the effect of the heat. The heaps vary in size, being from six thousand to about twenty thousand tons in content. At one of the works under consideration, there are about fifteen of the mounds or ridges of shale, each being one hundred and twenty to one hundred and eighty feet in length, with a base of about twenty feet, and a height of fifteen.

Fig. 87 shows the arrangement of the field.

The mounds are commenced by making a few fires of coal along the intended length, and covering them over with stones or bricks in any convenient manner, leaving lateral ducts, or passages, for the air to enter. Next, the shale is thrown on the fires, the coarsest first; and according as it ignites, and communicates heat to the outer portions, more of the mineral is thrown upon it successively, till the heap is considered large enough, so as to have the whole at that state of ignition which practice leads the manager to judge most advantageous. It is then *mantled*, as the workmen term it, that is, covered over with a layer of the already calcined and exhausted ore, in order to protect it from high winds and excessive rains, as also to moderate the heat and let it cool gradually, so that the sulphur present may not be volatilized or sublimed. From three to twelve months, according to the state of the weather, are generally required to calcine the heap properly; and in rough weather very little progress is made: this time includes the period of cooling the burned ore, which is done either by leaving the heap to itself, or checking the ustulation with a thicker mantling.

By an economical arrangement of the manager, the several mounds are in various stages of advancement, some being cold, others about being finally mantled for cooling, many in progress, while a further number are commencing, so that at all times a supply of calcined shale may be ready for the liquefying vats.

At Whitby, the calcining heaps are raised from eighty to a hundred feet in height. In consequence of the greater amount of carbonaceous matters which the shale at these works contains, the temperature of the mounds rises too high, and causes a loss on account of the excess of sulphurous and sulphuric acids sublimed; this is partly prevented by mixing the shale with some of the calcined and exhausted ore, and when the heap has acquired a larger size, and the heat is still deemed too high, either the crevices are plastered up with the small schist, or the whole is mantled over as at Hurlet. It would appear that the height of the heap must be disadvantageous to the manufacturer, on account of the difficulty of properly regulating the heat in so large a mass of material, and that the method followed at the Hurlet works effects a better ustulation, while at the same time it is more under control.

About one hundred and thirty tons of the Whitby calcined schist yield one ton of alum. In this humid climate it is found advisable to pile up on the top of the ridge of brushwood or coal and schist, a pyramidal heap of the mineral, which, having its surface plastered smooth, with only a few air-holes, protects the mass from the rains, and at the same time prevents the combustion from becoming too vehement. Should heavy rains supervene, a gutter must be scooped out round the pile for receiving the aluminous lixivium, and conducting it into the reservoir.

A continual but very slow heat, with a smothered fire, is most beneficial for the ustulation of alum slate. When the fire is too brisk, the sulphide of iron may run with the earthy matters into a species of slag, or the sulphur will be dissipated in vapor, both of which accidents would cause a deficiency in the produce of alum. Those bituminous schists which have been used as fuel under steam boilers, have suffered such a violent combustion, that their ashes scarcely yield any alum. Even the best regulated calcining piles are apt to burn too briskly in high winds, and should have their draught-holes carefully stopped under such circumstances. It may be laid down as a general rule, that the slower the combustion the richer will the roasted ore be in sulphate of alumina. When the calcination is complete, the heap diminishes to one half its original bulk; it is covered with a light reddish ash, and is open and porous in the interior, so that the air can circulate freely throughout the mass. To favor this access of air is another reason that the masses should not be too elevated; and in dry weather a little water should be occasionally sprinkled on them, which, by dissolving some of the saline matter, will make the interior more open to the atmosphere.

When the calcined mineral becomes thoroughly cold, it may be submitted to the lixiviating vats. As many weeks, or even months, may elapse, from the first construction of the piles or beds till their complete calcination, care ought to be taken to provide a sufficient number of them, so as to have an adequate supply of material for carrying on the lixiviating and crystallizing processes during the course of the year. The beds are known to be sufficiently decomposed by the efflorescence of the salt, by the strong aluminous taste of the ashes, and by the appropriate chemical test of lixiviating an aliquot average portion of the mass, and seeing how much alum it will yield with a solution of sulphate of potassa, or chloride of potassium.

SPENCE, who lately sealed a patent for the manufacture of alum, offers the following as his method of calcination. He forms on the ground a number of air-channels, by laying parallel lines of common bricks at the distance of four inches apart, and placing others on these crosswise; thus the channel formed is about four inches square. Tho transverse bricks are placed on loosely, so as to allow the air to pass freely upwards; burning coals are laid on the channels, and a layer of the shale which is most bituminous, broken into small pieces; and as the combustion proceeds, other layers of the shale fragments, less bituminous than the preceding, are put on continuously, but not in too great a quantity. The thickness of each layer should be regulated by the briskness of the combustion, which should never go beyond a low red heat; but care must be exercised in maintaining the bed at this point, as a higher temperature would be apt to glaze or partially flux the materials, and render the alumina less soluble in acid. An examination of the following figure, exhibiting the heaps or mounds in various stages of progress, will show that a method similar to this is practised at Hurlet.

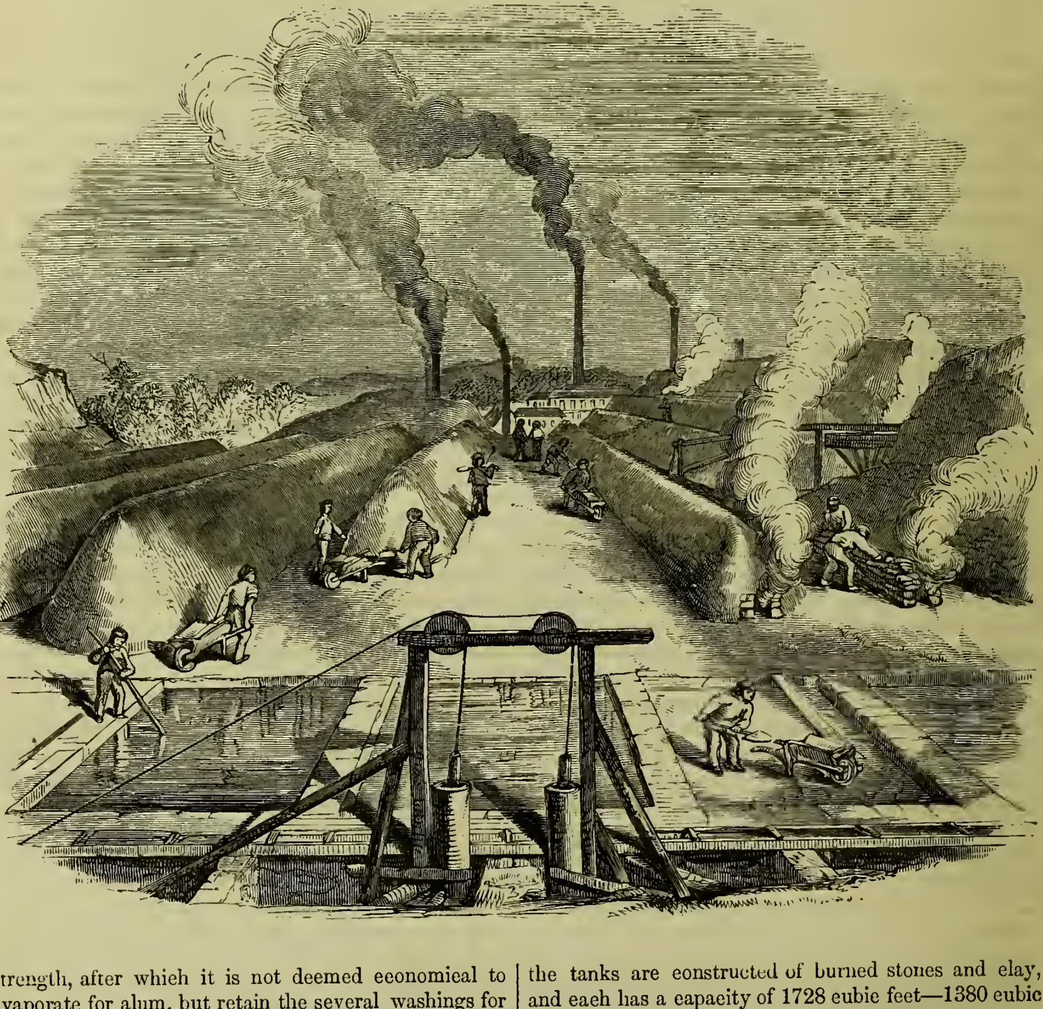
Shales destitute of bitumen, or prepared clays, may be calcined in the same way, by mixing with them small coals, or saw-dust; the heaps in either case may be made of any convenient dimensions, but the height most appropriate is four to five feet. The mass will burn out, and be cool enough for use in eight or ten days.

Lixiviation of the Roasted Ores.—This part of the operation for dissolving out the sulphate of alumina, and other soluble components, is one which requires much attention in regulating the proper amount of water which is required to extract the whole of the soluble bodies, without having a superabundance of unnecessary liquid to eliminate when the solutions are to be subsequently concentrated for crystallization, or precipitation. When an excess of water has been employed to exhaust the calcined shale, considerable time and labor are required for the evaporation of such liquors. If a manufacturer allows too much to be taken, he cannot compete with his neighbor who uses his best endeavors to cheapen the cost of production, especially in this age of rivalry. Hence, the chief study should be to employ only as much water as will effectually or nearly exhaust the ore of its soluble saline ingredients. Vessels for the lixiviation are either wooden cisterns lined with sheet-lead, or cisterns made of stone; the latter are more durable, but more expensive. The tanks, or lixiviating vessels, are placed in England and France at different levels, for the purpose of facilitating the exhaustion of the material in them, while in Scotland they are constructed upon the same plane. The form usually given to these vessels is that of a square or oblong.

When the exhaustion of the ustulated shale is effected by the first of these arrangements, as at Whitby, a wooden or iron sluice carries the lie from the series of tanks to a large cistern to be again returned upon the upper troughs, recharged with fresh portions of the burned ore, in order to bring it to the proper degree of strength, when it is drawn off to be concentrated by heat. Water is let into the upper troughs through several inlets, till it covers the burned material to the depth of one or two inches. After six to twelve hours, according to the facility with which the sulphates are extracted, the liquor from this tank is drawn off at the openings at the bottom into the cistern next beneath it, where it is suffered to remain for an equal length of time before it is run into the clarifying vessel, whence it is conducted to the pans for evaporation. No more than half the water employed in the first washing can be drawn off, as nearly half is retained by the shale; and, in consequence of this, only half the quantity of water used in the first is added to make the second lie, which, after twelve hours, is drawn off into the lower cistern, like the preceding, and a third quantity of water is poured on in order to extract the whole of the soluble ingredients. This third washing being of a low strength, is pumped up to form the first watering of fresh quantities of the material, to bring it to the desired strength for evaporating, which should be from 1·113 to 1·157.

At the Hurlet and Campsie Works, near Glasgow, the process pursued is the following:—After the ore is calcined, it is wheeled from the ridges into large stone cisterns, called *steeps*, occupying the same level —see Fig. 87. The steeps are furnished with false bottoms formed of planks, which rest on transverse beams, and the roasted shale is laid on the planks till it is about eighteen inches above the bottom. Water, or a weak lie from a previous operation, is poured upon the bed of adusted ore till it is completely covered over, and afterwards allowed to remain in contact with it for about eight hours. It generally remains over the night. A plug at the bottom of the vat is then opened, and the solution, which should have a specific gravity of about 20° Twaddle, or 1·100, is drawn off into the *settler*, or supply cistern, where it is allowed to remain at rest, in order that any matters held mechanically may subside. A second wash, of a weaker liquor than that employed in the first operation, is then added, and left in contact with the partly-exhausted shale as long as in the first instance, after which it is drawn off to the cistern as before; the same operation is repeated a third time if necessary, till the liquid becomes below 12° Twaddle in strength, after which it is not deemed economical to evaporate for alum, but retain the several washings for use in exhausting fresh quantities of ore. The last washings of the steep are made with water, and the strongest of the several resulting weak liquors from each steep is used the first in exhausting a fresh one. After the ore is deprived of its soluble ingredients, it is either removed to the waste heap, or returned to the calcining ridges, where it is intermixed with the fresh ore for the purpose of checking a too rapid combustion, when such is apt to take place.

Fig. 87.



At Valmunster, in the department of the Moselle, the tanks are constructed of burned stones and clay, and each has a capacity of 1728 cubic feet—1380 cubic feet Rhenish. At the bottom, at certain distances from each other, beams are arranged, upon which a layer of straw and brushwood is laid, and upon this the false bottom of boards is placed. This arrangement forms the filtering apparatus, from which the lie flows through apertures at the sides. Each cistern requires 1280 cubic feet of water for the lixiviation. Lie is first poured upon the ore, of 20° B. = sp. gr. 1·157; when this has run off, it corresponds to 24° or 25° B., and is fit for boiling; a weaker lie of 15° B. = sp. gr. 1·113, and subsequently others of 10° B., = sp. gr. 1·072, and the weakest, of 5° B., = sp. gr. 1·034, then follow; and lastly, the whole is washed out with pure water. All the lies that fall short of 24° or 25° B., are poured upon more or less exhausted ores, according to their strength. By arranging these cisterns upon terraces, the one above the other, the lie can easily be drawn from the upper into the lower cisterns, until it has acquired the proper strength. The solution is then called crude liquor, and is preserved in large walled tanks, ready for further operations.

The density of the liquors is determined by a specific gravity bottle, peculiar to the alum manufacturers; it is capable of containing eighty pennyweights of water at the ordinary temperature, and when this bottle is filled with the alum liquor and weighed, the excess of weight is denominated the strength in pennyweights; thus, if a liquor should weigh ninety pennyweights, it would be put as one of ten pennyweights, or simply liquor of 90. A simpler method is the use of the hydrometer, for determining the amount of ingredients dissolved, and this even in the pennyweights of the alum-maker; thus, dividing the indications of Twaddle's hydrometer by 2·5, gives the alum-maker's strength in pennyweights, without the trouble of weighing.

According to SCANLAN, eight different liquors are met with in the alum-works on the Yorkshire coast.

1. *Raw liquor.*—The calcined alum shale is steeped in water till the liquor has acquired a specific gravity of nine or ten pennyweights, according to the language of the alum-maker.

2. *Clarified liquor.*—The raw liquor is brought to the boiling point in leaden pans, and suffered to stand in a cistern till it has become clear; it is then called clarified liquor. Its gravity is raised to ten or eleven pennyweights.

3. *Concentrated liquor.*—Clarified liquor is boiled down to about twenty pennyweights. This is kept merely as a test of the comparative value of the potassa salts used by the alum-maker.

4. *Alum-mother liquor.*—The alum pans are fed with clarified liquor, which is boiled down to about twenty-five or thirty pennyweights, when a proper quantity of potassa salt in solution is mixed with it, and the whole run into coolers to crystallize. The liquor pumped from these rough crystals is called *alum-mothers.*

5. *Salt-mothers.*—The alum-mothers are boiled down to a crystallizing point, and afford a crop of *rough Epsom,* which is a sulphate of magnesia and protoxide of iron.

6 and 7. *Alum-washings.*—The rough crystals of alum—No. 4—are washed twice with water, the first washing being about four pennyweights, the second about two and a half, the difference in gravity being due to mother-liquor clinging to the crystals.

8. *Tun-liquor.*—The washed crystals are now dissolved in boiling water, and run into the roching-tuns—wooden vessels lined with lead—to crystallize. The mother-liquor of the *roch-alum* is called *tun-liquor;* it is of course not quite so pure as a solution of roch-alum in water.

With reference to the exhausted residues, two cases may occur: they have either been rendered perfectly porous by the roasting and decomposition, in which case they will have been completely exhausted, and may be thrown away unless they can be used for covering fresh heaps; or they still contain portions of undecomposed ore, and may then be subjected to a second exposure—as at Buchsweiler, in Elsace—either by themselves or mixed with fresh ore.

The process in many other alum-works, where the ores do not require roasting, is essentially the same as that described above. The lixiviation, however, is then carried on with the heaps themselves, and during the process of decomposition; they are erected for this purpose either upon flat wooden boxes, termed Bühnen, or upon a foundation composed of brickwork, or clay, which is completely impervious to the liquor, and where the water which is pumped from time to time upon the heap collects, and is thence conducted to the crude liquor cisterns. The soluble salts are thus removed at certain periods, as they are produced during decomposition. The strength of the crude liquor in the cisterns must be regulated by the respective prices of labor and fuel, weak liquor requiring more of the latter, and strong liquor more labor; it is never advisable, however, to concentrate the liquor to that degree at which it would be saturated with the crystallizable salts, such as green vitriol and sulphate of magnesia, as these would crystallize with the slightest amount of evaporation or rise of temperature before it is desirable they should do so. In general, the density indicated by 20° B., = sp. gr. 1·157, is not exceeded. SIMON found the crude liquor from Gleissen, in Newmark, to contain the following ingredients:—

Sulphate of alumina,	11·085	= 29·678
Sulphate of iron,	9·773	
Sulphate of soda,	2·035	
Sulphate of magnesia,	1·754	
Sulphate of manganese,	0·174	
Sulphate of potassa,	0·095	
Sulphate of lime,	0·120	
Sesquichloride of iron,	1·872	
Chloride of magnesium,	0·334	
Sesquichloride of aluminum,	0·419	
Sulphuric acid,	0·563	
Hydrochloric acid,	1·454	
Water,		70·322
		100·000

These constituents are always accompanied by a certain quantity of ready-formed alum, which may be potassa, or ammonia alum, or both, when a red heat has not been employed in the manufacture; but if a high temperature be applied, it decomposes the ammonia alum, leaving only alumina. To the production of the potassa alum, the alkali naturally contained in the ores contributes, and still more that which exists in the ash of the wood used as fuel; the production of ammonia is attributable to the nitrogen contained in the coal. During the time that the crude lie is clarifying in the large vats, a chemical decomposition ensues by the action of the air upon protosulphate of iron, which is not prevented by the state of solution of the salt.

10 Eqs. of sulphate of iron, $Fe\,O, S\,O_3 = Fe_{10} + O_{10} + 10\,S\,O_3$

absorb from the air 5 eqs. of oxygen, $= \quad O_5$

producing .... $Fe_{10} + O_{15} + 10\,S\,O_3$

Which consists of a basic salt that precipitates,...................... $= Fe_4 + O_6 + S\,O_3$

and 3 eqs. of sesquisulphate of iron which remain in solution,... $= Fe_6 + O_9 + 9\,S\,O_3$

$Fe_{10} + O_{15} + 10\,S\,O_3.$

In the foregoing analysis, this acid salt has probably been overlooked, or its constituents have been appropriated in some other manner; in the high state of dilution of the crude lie, however, nearly the whole of the oxide of iron is precipitated, and a very small portion remains in solution. This behavior is turned to account by mixing the crude liquor with the mud obtained in a subsequent operation; this mud is a kind of basic alum, that is soluble and deficient in a certain quantity of sulphuric acid to make it neutral alum, but which is supplied at the expense of the acid sesquisulphate of iron, or of the free sulphuric acid. The basic sesquisalt of iron is called in German *vitriolschmand*, and is collected from time to time from the bottom of the cisterns, and heated to redness; it then parts with its acid, and the peroxide remains, which is used as a red pigment.

Boiling the Crude Lie.—The further treatment of the lie depends upon the quantity of green vitriol which it contains, and in most cases there is quite as much or more of this salt than of alum. When this happens the lie is used for the production of both salts, and alum and copperas works are generally carried on conjointly. The process of separating the two salts by crystallization varies much in different manufactories.

When the crude lie is very much charged with the iron salt, it is evaporated in pans, into which old iron is thrown. The sesqui-compound formed by the action of the air is thereby partly precipitated as a basic *salt*, with the liberation of sulphuric acid which converts a part of the iron into sulphate, setting free hydrogen gas; the latter reduces the precipitated sesquisulphate of iron to protosulphate, and *prevents* its further oxidation during the evaporation. In order to afford more points of attachment for the crystals, and facilitate their removal, the workmen are in the habit of hanging peeled sticks and branches in the solution. The mother lie contains the whole of the sulphate of alumina, which is separated in a manner to be subsequently described.

In other places—as at Reschwitz, near Saalfield, at Schwemmsal—the greater portion of the water is removed by graduation, as in the salt-works, when, in consequence of the increased action of the air, a considerable portion of the green vitriol is decomposed, and much basic sulphate of iron, mixed with gypsum, is left as an incrustation upon the thorns. The graduated lie then yields green vitriol on evaporation, and a mother liquor containing the alum.

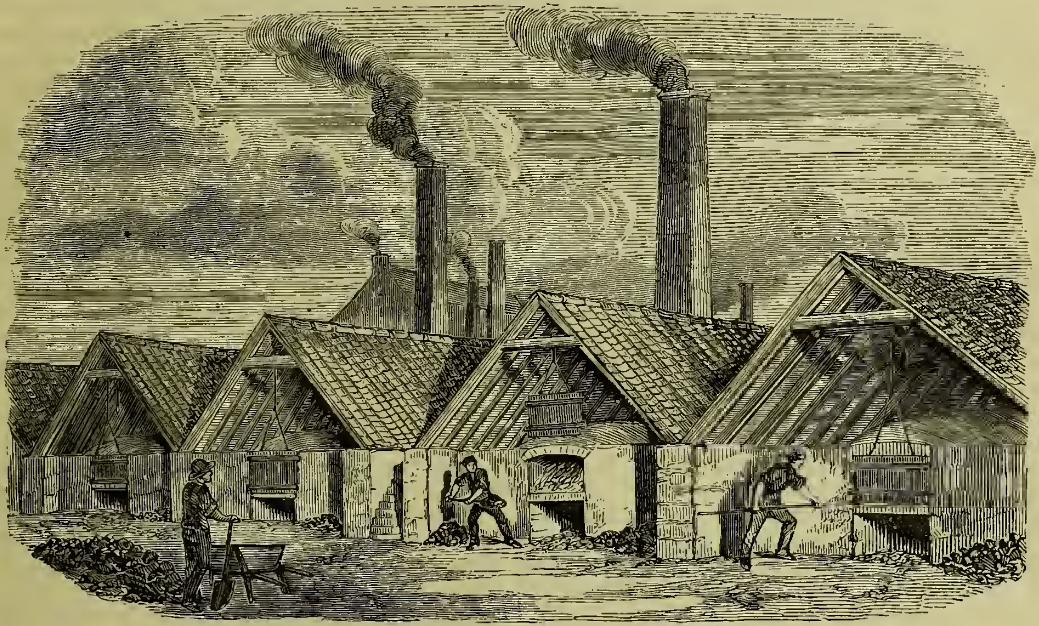
Another process consists in separating the copperas, not by cooling the saturated solution, but by simple evaporation, or abstraction of water, as in the soccage of common salt—for instance, at Buschweiler. When evaporation has been carried on for some time, and the loss of water and the strength of the lie have reached a certain degree, a point of saturation is attained—when the specific gravity is from 1·35 to 1·37, or 38° to 40° B.—at which the remaining water is just sufficient to retain the copperas in solution. The evaporation of every additional quantity of water then causes the precipitation of a portion of copperas, and a sediment, consisting of very small anhydrous or slightly hydrated crystals, is rapidly deposited. In the meantime, the evaporated water is constantly replaced by fresh liquor. It is obvious that, upon this plan, in which the liquor is always saturated, the quantity of dissolved copperas cannot accumulate in the pan, whilst the amount of the other soluble salt—sulphate of alumina—must increase synchronously with the deposition of the former until the liquid is saturated with it—a stage which is carefully attended to by observing if the hydrometer sinks to the same degree, in order that the other salts with which it will then be saturated may not precipitate with the copperas. On the one hand, the precipitated copperas is removed and purified by recrystallization, when its water of crystallization is raised to seven equivalents, and on the other a mother liquor remains, saturated with sulphate of alumina, for the production of alum.

When, on the contrary, the copperas is not in excess, the process is reversed, and begins with the production of alum from the crude liquor. For this purpose the lie is pumped at once from the crude liquor cisterns, in which it has been clarified, into the evaporating pans to be brought to the proper degree of concentration. If the pans are composed of tinned iron, they will be corroded by the sulphate of alumina and the lie, with the evolution of hydrogen and the precipitation of basic sulphate of alumina; this action, which is similar to that of an acid, is not prevented by the addition of the basic mud before mentioned. The sediment frequently gets burnt on the bottom, and causes difficulty and damage, particularly when cast-iron or leaden pans are employed, which are not otherwise affected; but the former of which are brittle, and the latter too easily melted by the heat. To prevent this burning, metal evaporating pans are now almost universally discarded, and the flame is carried over the surface of the liquid instead of below the pan. When, however, the liquors contain sulphate of magnesia, surface evaporation will not be so available as evaporation carried on in leaden pans heated from below, for when the concentration has proceeded to a certain extent, the magnesian and other salts form a crust on the surface of the liquid which protects it from the heated air passing over it.

At each of the Hurlet works there are six or seven evaporating basins, protected from the cooling influence of the atmosphere and rains by a shed-roofing, as represented in Fig. 88. These are long cisterns of brickwork, well cemented together, and arched over with the like materials; they have a length of sixty feet, and a breadth of six, with a depth of about four; they are capable of evaporating about four thousand five hundred to five thousand gallons in twenty-four hours. The cisterns are heated by a furnace, which is placed at one end, and on a level almost with the surface of the liquid when the boiler is full, as has been already described; a powerful chimney at the opposite end of the boiler creates a strong draught, that sweeps the flame and heat from the fire over the surface of the liquor, producing a very high temperature, and rapid evaporation takes place. Fig. 89 represents a longitudinal section of one of these evaporating cisterns.

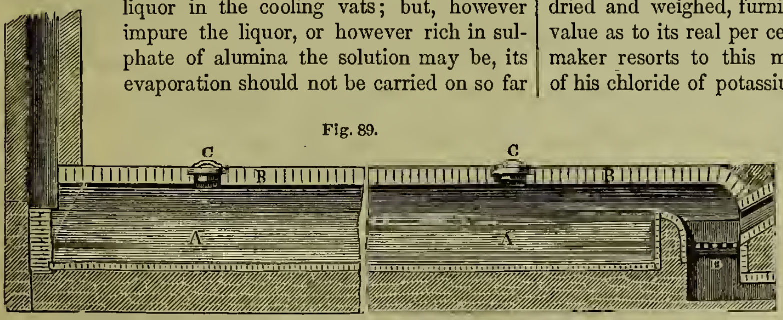
The liquor is placed in the basin, A A, the walls of which are made of brick, placed upright, and well cemented with mortar composed of lime and lixiviated alum-shale waste. In order that the current of air passing through the fire at D, may not carry any appreciable quantity of the ashes into the liquor, in course of evaporation, the fire bars are fixed at a low level; the flame passes below the flat arch, B B, to the chimney. This arch contains apertures, C C, adapted for observing the interior of the different parts. Fresh liquors, or the mother liquors from a previous operation, are introduced through the openings, C C, as the water is evaporated from the contents of the furnace, until the solution acquires a density of about 1·40, which is the most suitable state of concentration for producing the flour, or meal, in the next operation.

Fig. 88.



To economise fuel, the furnace is very long, and the fire communicates with an evaporating pan, so that, in either case, the whole heating power may be made available, as far as practicable. The draught of the furnace insures, in the simplest manner, a constant current of air over the liquid, which is favorable to evaporation by sweeping the vapors generated onwards to the chimney. During the evaporation of the liquor in the furnace, a copious sediment is thrown down, consisting of basic sulphate of iron—produced by the continuous decomposition of the copperas and neutral sesquisulphate of iron—gypsum, and other salts, of which it is necessary to clear the liquor in the cooling vats; but, however impure the liquor, or however rich in sulphate of alumina the solution may be, its evaporation should not be carried on so far as to cause a deposition of salt upon cooling; the ingredients must be entirely held in the clear solution, even after cooling the liquor in the vats appropriated to the production of the alum flour.

Fig. 89.



In the forementioned factories, the furnaces are fired incessantly for eight days, and the boiler is replenished with liquor from the supply cistern till the eve of the eighth day, when a charge of mother liquor is run in which deposits no sedimentary matter on boiling, like the fresh liquor; this is boiled down till it has the proper degree of strength, and then allowed to settle for twelve hours. After adding the mother liquor, it is customary to find the strength of the solution. This is done by taking out a known quantity of it, and concentrating it to the proper strength with chloride of potassium, allowing the solution to cool, and, after twenty-four hours, the crystals produced, when washed with a little cold water, dried and weighed, furnish an approximate test of the value as to its real per centage of alumina. The alum-maker resorts to this method for testing the quality of his chloride of potassium; but in this case he has a standard solution of aluminous sulphate. These experiments point out the quantity of alkaline chloride to be added per gallon of liquor.

At the Whitby alum-works, leaden pans are employed in consequence of the liquors from the calcined shale of this locality containing sulphate of magnesia, which renders surface evaporation as at Hurlet inapplicable, as already explained; the pans are ten feet long, four feet nine inches wide, two feet two inches deep at one end, and two feet eight inches at the other. In these lead pans the liquor is rapidly concentrated by a fire at one end, the flue of which runs along in parallel channels under a plate or course of brickwork on which the pans rest. Every morning the pans are emptied into a settling cistern of stone or lead. The specific gravity of the liquor should be about 1·40 to 1·50; this density must vary, however, with different kinds of lixivia, and according to the views of the manufacturer. For a liquor which consists of two parts of sulphate of alumina and one of sulphate of iron, a specific gravity of 1·25 may be sufficient; but for a solution of one part of sulphate of alumina and two parts of sulphate of iron, which latter is to be abstracted by crystallization, a density of 1·40 is requisite

PREPARATION OF THE POWDER.—From the evaporating basins, the liquor is run into the flour or powder cisterns, in which the sulphate of alumina is combined with potassa or ammonia—the *flux* or *precipitating substance*—in such a manner as to effect the first purification of the alum. The alum is only very slightly soluble in *the cold* mixture of the liquor with the solution of the precipitating substance, and for this reason the greater portion of it separates in the form of minute crystals, or *flour*, from the solution; the agitating motion given to the liquor in the cisterns favors the formation of the crystals. To obtain the largest yield of flour, it is necessary to add the precipitating solution as strong as possible, which is done by dissolving it in the least quantity of boiling water. The proper amount of the precipitant should be determined, as near as possible, by a preliminary experiment on the small scale; but still these data, though they serve to give an idea of the quantity, do not correspond always with the extensive operations of the manufacturer; so that even when previous experiments are made, to ascertain the true quantity to be added, much caution is necessary when operating on the whole bulk of mother liquor, as an excess of the precipitant may often cause much future inconvenience and labor. The best precipitating substances are potassa or ammoniacal salts, as they form alums which are very insoluble in cold water; only 9·25 parts of the potassa alum, and 9·16 parts of the ammonia alum being dissolved by a hundred parts of water at 50° Fahr. Soda salts are very disadvantageous precipitating agents in the formation of alum, on account of the great solubility of the resulting compound, forty-six parts of which are dissolved by a hundred of water at 50° Fahr., and, therefore, they are seldom used.

In the event of potassa salts being employed, preference is given to the chloride of potassium or sulphate of potassa; of the latter, 50·9 parts are required to precipitate one hundred parts of sulphate of alumina, from which results three hundred and thirty-four parts of crystallized alum. The preceding enumerated tests, however, will not answer in the factory, because the mother liquor is indefinite as to the amount of impurities which accompany the aluminous sulphate. To show the nature of this more clearly, let it be supposed that the mother liquor is saturated with sulphate of iron and sesquisulphate of alumina, and that its temperature is 50° Fahr. In this case, it will contain, for every

100· parts of water,
33·2 parts of anhydrous protosulphate of iron, and
33·5 parts of anhydrous sesquisulphate of alumina.

To precipitate these products, 17·1 parts of neutral sulphate of potassa are required, for the solution of which, sixty-six parts of boiling water will be necessary.

On mixing this solution with the lie, ninety-six parts of alum will be produced, together with the accumulated water of the lie and precipitant, which, collectively, will amount to one hundred and sixty-six parts. Of the ninety-six parts of alum formed, only sixteen can remain in solution after the liquid has cooled to the primary temperature of 50° Fahr.; therefore, eighty parts will separate in the crystallized state; but, in practice, this quantity diminishes according to the less saturated state of the lie. Since chloride of potassium is more soluble in boiling water than the sulphate of potassa, it is preferable for precipitating the alum flour; the chloride is soluble in two parts of boiling, and in three parts of cold water, and hence the mixture may be made in the cold.

In the instance cited above, the 33·5 parts of sulphate of alumina would require 14·5 parts of chloride of potassium for precipitation, which would be taken up by 26·2 parts of boiling water, and produce 96·5 parts of alum.

The mixture being made, and the precipitate subsided, twelve parts of the alum would be held in solution, so that only 84·5 parts of flour are thrown down in the solid form. If the same quantity of the chloride of potassium be dissolved in cold water, forty-six parts, at 50° Fahr., will be required, which, when added to the 23·5 parts of sulphate of alumina in solution, will yield eighty-four parts of alum as a precipitate, while 13·8 remain dissolved: in both cases, the difference is immaterial whether the precipitant be dissolved in hot or cold water.

Another precipitant which is used with much advantage, on account of its great solubility, is sulphate of ammonia; it is soluble in two parts of water, but the alum obtained when the sesquisulphate of alumina is precipitated with it, is less than when the potassa salts are employed, in the proportion of 100 : 95·6. The reason of this is, that the atomic weights of these two bodies differ, the hydrate of ammonia being 26, while the potassa is 47.

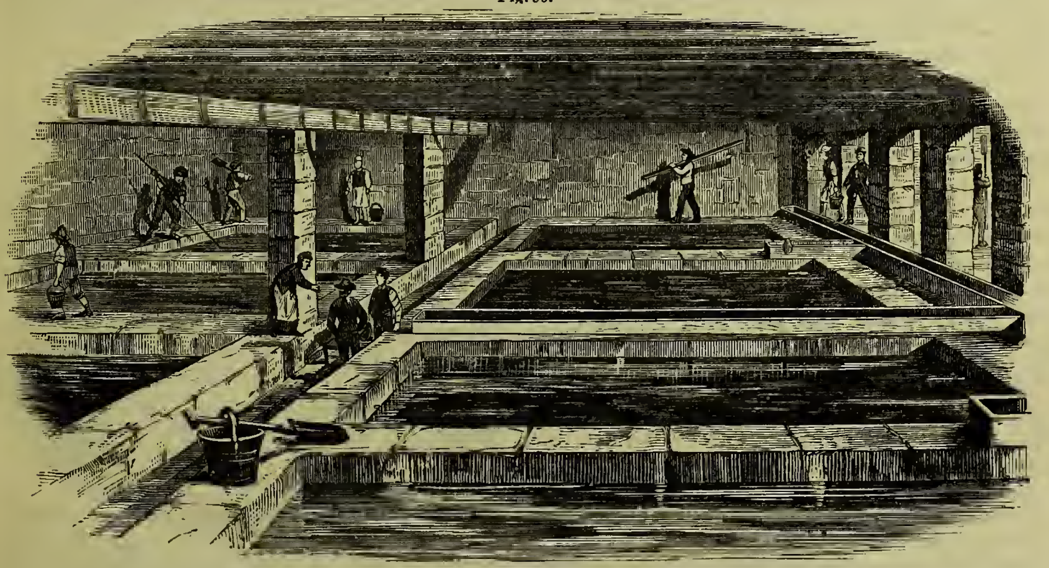
To recur to the foregoing example, the 33·5 parts of sulphate of alumina will take 15·8 parts of sulphate of ammonia to form with them 87·7 parts of alum, of which 77 parts are precipitated, and only 10·6 retained in the solution; thus, the disadvantage arising from the lesser equivalent of ammonia-alum is counterbalanced by the greater solubility of the ammoniacal salt as a precipitating agent.

The sulphate of potassa—for the use of alum-makers—is obtained as a secondary product in the manufacture of nitric acid, and in the purification of potassa, and the crude carbonate of that alkali: thus produced, it is a bisulphate of potassa, the composition of which is expressed by the symbols HO, SO_3, KO, SO_3, and cannot be employed as such till the excess of acid is neutralized by fresh additions of the caustic or carbonated alkali to form a neutral sulphate of the composition, KO, SO_3.

In no other case can the caustic alkali, or carbonate, be employed in the preparation of the alum flour, for if no free acid be present to unite with it when added, it would invariably throw down a basic double sulphate of alumina and potassa, which is insoluble in water, though redissolved by a further addition of bisulphate of potassa. A greater or less quantity of this compound is always formed during the evaporation of the liquors, in consequence of the iron present abstracting some of the acid, but, as in the preceding, a slight addition of the bisulphate of potassa redissolves it.

Knapp recommends that the purification of crude potassa and its carbonates should be conducted on the same premises with the alum-works, for the purpose of turning to use the bisulphates and chloride formed in this operation as precipitants of the alum. With regard to the latter salt, he says it is of greater importance than the sulphate, inasmuch as it effects the decomposition of the sulphates of iron, giving rise to sulphate of potassa, and chlorides of iron, which are highly deliquescent salts, and from which the alum flour can be removed with greater ease and perfection than from the sulphates of this metal. But the decided advantage attending the use of the chloride, is when a sesquisulphate of iron is present in the lie, as this salt, in combination with sulphate of potassa, forms a difficultly soluble though not insoluble double salt—basic iron alum—which would precipitate in the form of a yellow powder, and contaminate the alum flour. As an excess of the chloride of potassium would convert the sulphate of alumina into chloride of aluminum, a result which would entail a loss, he recommends that the lie should be examined before each operation, with a view to determine the proper amount of chloride to be added, as it happens that the quantity required to precipitate the whole of the alumina as alum, seldom or never meets with sufficient sulphate of iron in the lie to be converted into sulphate of potassa. This examination is conducted as follows:—A saturated solution of the precipitating salt is taken and added from a burette, or other graduated vessel, to a measured quantity of the liquor, the mixture being briskly agitated at each addition; successive portions of the reagent are to be poured in as long as the flour thrown down increases in quantity, and when no further precipitation is observed, the number of measures is read off, which, for sufficient accuracy on the large scale, will stand for the amount of solution required to precipitate a certain amount of the liquor; by this means, the tedious process of weighing is avoided. If sulphate of potassa has been employed, from its difficult solubility in the cold it may precipitate during the cooling of the liquor, apparently increasing the bulk of the precipitate, and giving rise to an error in the calculation. To avoid this source of inaccuracy, it is best to employ, as the testing liquor, a saturated solution of sulphate of ammonia, which being very soluble, both in hot and cold water, no precipitation of this reagent can take place; one part of the ammoniacal salt is equivalent to 1·32 parts of sulphate of potassa, or 1·13 of chloride of potassium.

Fig. 90.



Chloride of potassium, for the use of the alum-maker, is obtained in large quantities from the waste liquor of the soap-works—soap-boiler's waste—from saltpetre refineries, and from the glass-houses. Wood ashes should never be used in the manufacture, on account of the lime which they invariably contain.

The most fruitful source of the ammoniacal reagent in use, is the liquor from the gas-works where coals are distilled; this is converted into sulphate of ammonia, either by the addition of sulphuric acid directly, or by the decomposition of sulphate of lime or iron, which has the effect of converting the ammonia into sulphate, as will be subsequently described. The crude ammoniacal liquor obtained from the manufacture of chloride of ammonium, by the destructive distillation of animal matters, may be employed with equal advantage for the same purpose.

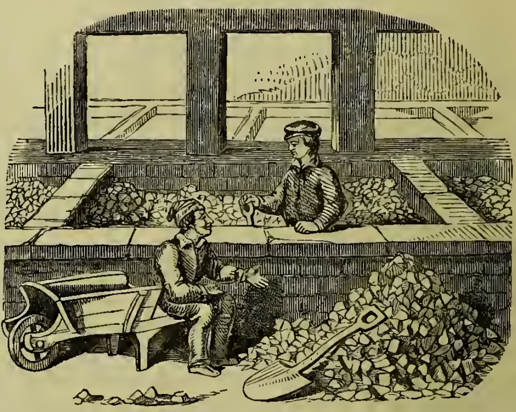
At Mr. KING'S works, both at Campsie and Hurlet, only potassa-alum is fabricated, and the chloride of potassium is used as the precipitating agent. At Messrs. WILSON'S factory, a large proportion of ammonia-alum is made, and most of the liquor from the gas-works in Glasgow, Paisley, and neighborhood is used for this purpose: when the works are in full operation, two thousand gallons of the gas liquor are consumed daily in yielding the ammonia, which is converted into sulphate with vitriol made on the premises.

Having prepared the aluminous liquor as already instructed, in the evaporating furnaces, and ascertained the content of salts per gallon, the concentrated solution of the precipitant being at hand, the crystalline flour is precipitated by gradually adding it to the aluminous solutions, the mixture being kept briskly agitated for some time, till the whole of the powder is thrown down. A slanting plane is fixed adjacent to the precipitating vessels, on which the workmen shovel the subsided powder, for the purpose of freeing it from the impure mother liquor of the vessel; the portion of lie adhering to the crystals drains off, and runs back to the mother liquor; still it does not wholly separate by this means, a small portion being mechanically retained by the mass of powder, which produces the brownish-yellow color of the crystals after the first draining. To remove the color, recourse is had to another process called *washing*. For this, it is sufficient to stir the powder with a small quantity of water in an appropriate tank or vat. The impurity mixed with the crystals is taken up by the water, as likewise a small portion of the alum, and when the substance has subsided, the liquor is drawn off by means of a siphon; two washings are found sufficient to separate all adhering foreign soluble bodies. The water employed in washing the flour should be of as low a temperature as possible, as the quantity of alum dissolved out is in proportion to the temperature of the water.

Fig. 90 is a view of the precipitating and crystallizing cisterns at one of the Hurlet works; they are constructed of stone, well adjusted and embedded in tempered clay, on a site contiguous to the evaporating furnaces. Having ascertained the quantity of sulphate of alumina per gallon in the concentrated liquor in those boilers, their whole bulk of lie is found by gaging, at the temperature of 60°. A corresponding amount of chloride of potassium, or sulphate of ammonia, is then weighed out and placed in one of the cisterns, after which the plug is removed from the boiler, and the liquor conducted along stoneware gutters to the coolers till it flows upon the heap of chloride. Sometimes the latter is gradually added to the liquor as it flows along in the gutters. Towards the end the mixture is well agitated to insure a complete solution of the alkaline salt and a uniform state of the liquor. In four or five days, when the plug is drawn out from the cistern and the mother liquor run off, the bottom and sides of the cooler are found lined with crystals of alum, generally some inches in thickness. This is called *first alum*, and is removed from the vessel to the draining stage, which is a raised platform in a sloping position, so that the mother liquor drains off from the heap, as shown in Fig. 91.

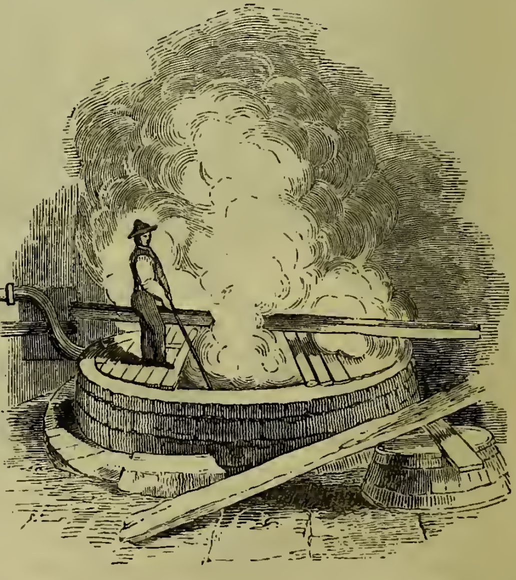
The first alum having been drained, is now washed to remove as much of the mother liquor from it as possible. For this purpose, tubs are filled with second alum mothers, or liquor which has been used in washing in a subsequent part of the process; and the alum, placed in wooden sieves, is rinsed in this liquor, and thrown on the stage.

Fig. 91.



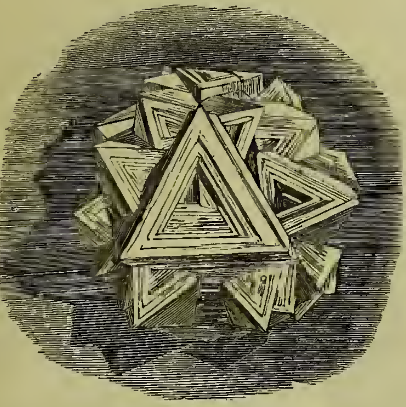
The second alum boiler, which is a deep stone cistern covered with wood—Fig. 92—is then prepared, by running in a quantity of liquor which had been previously used in washing the second alum; steam is next introduced, till the menstruum has nearly attained its boiling point, when the washed and drained crystals are thrown in, and constant agitation kept up. This is continued till as much alum has been added as will increase the specific gravity to 60° Twaddle, and the temperature is raised as much as possible by the steam, which is then

Fig. 92.



shut off, and the boiler being closely covered up, the liquor is allowed to remain at rest for twelve hours, for all the impurities to settle; the plug is then removed, and the clear liquor runs off to the second alum coolers, which, like the preceding, are sunk stone cisterns. In these it remains for four or five days, when the sides and bottom are found lined with alum, now nearly white, to the thickness of eight or nine inches. The small cup-like clusters of second alum crystals, which form on the surface of the coolers at this stage of the process, and successively fall to the bottom, assume the beautiful appearance exhibited in Fig. 93. The mother lie, which should have a specific gravity of 26°, is removed, and used for washing up the first alum as already described; and the crystals, being broken up, are affused with pure water, and drained, previous to the finishing process.

Fig. 93.



Crystallization.—The powder or alum flour, of minute, or imperfect crystals, prepared as before mentioned, is very seldom sent to market as such, the consumers of the article preferring to use the salt in the form of large crystals; they satisfy themselves likewise, that it is less liable to be adulterated with any other impurities when in a well-defined crystalline state, than if it were amorphous.

Crystallization of the alum flour, to answer the demand of the manufacturers who require it, and for sale to the public, is effected by dissolving it in as little boiling water as possible, and when no more of the substance is taken up, the saturated solution is run into crystallizing vessels, which are denominated *roching casks*, or *growing vessels.* Steam is better adapted than water for the purpose of dissolving the flour. A large wooden vessel, lined with sheet-lead, is provided for this purpose, and in the interior the powder is sustained occasionally on perforated shelves, so that the steam which issues from the pipe that enters at the bottom may have more extensive contact with it, and thus dissolve it more readily. As the steam penetrates through the several diaphragms bearing the powder, part is dissolved; that which is liquefied in the upper ones is concentrated by the hot steam as it falls down to the bottom of the vessel, and being hot, it is at once run into the vessels for crystallization.

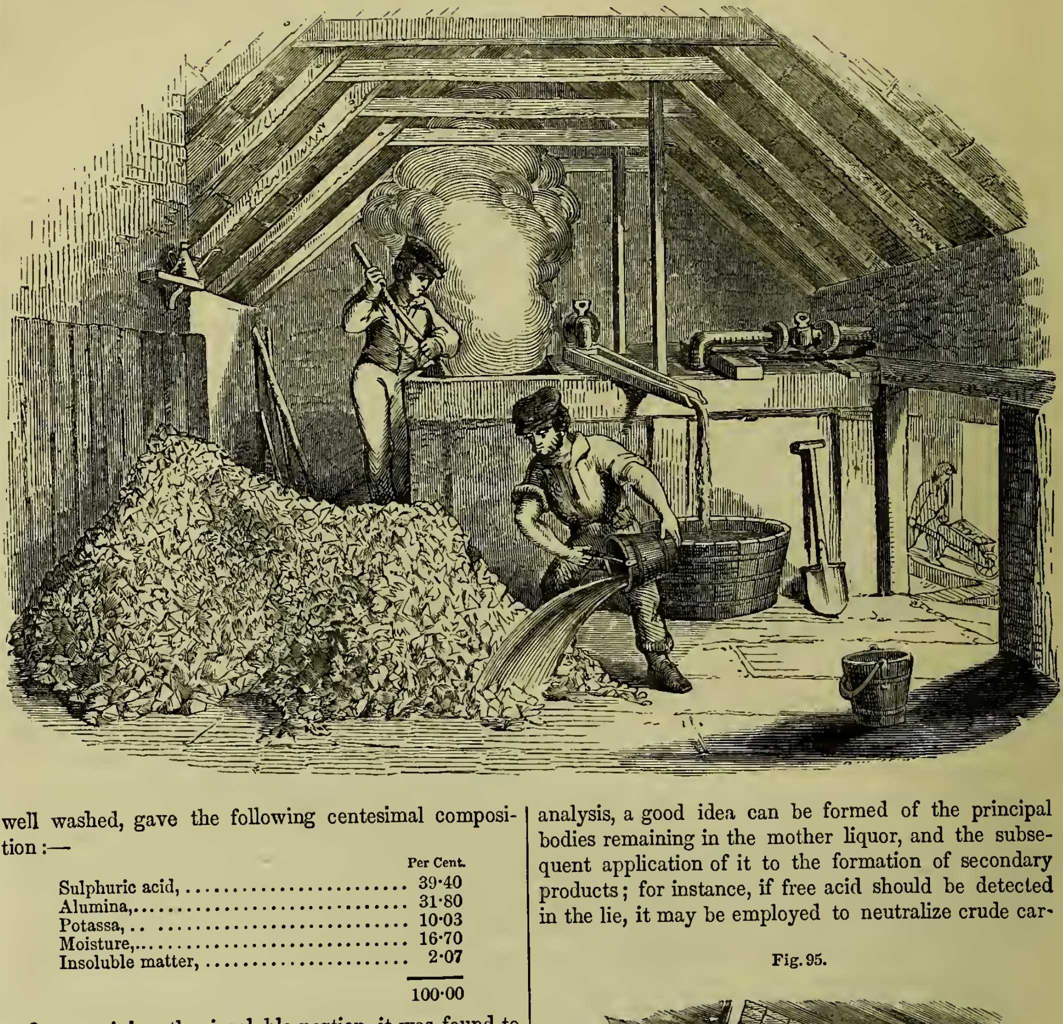
Fig. 94 is a drawing representing the roching-pan which is usually found in the extensive alum factories of England and Scotland; it works on the above principle, and is therefore advantageous in rendering a subsequent evaporation unnecessary. It is a large covered leaden cistern, into which steam is forced, and the alum is shovelled in to meet it; a solution takes place rapidly, without any addition of water. The temperature of this solution having reached 96°, the heat is raised as high as possible, generally to 224° Fahr., and the steam being shut off, the pan is closely covered up, and allowed to remain at rest for four or five hours, or till the temperature has fallen to about 200° Fahr. The water which has been used for washing the crystals, is again taken for washing the first alum, as above.

At Valmunster, this operation is carried on in vessels constructed as follows:—The wooden troughs are lined with lead in the ordinary way, but are closed by a lid in which are two openings; one of the openings receives the steam-pipe, and the other a wide leaden funnel. The sides of the funnel are perforated with small holes, three hundred of which are inserted in every square foot of surface. In this funnel the alum flour is placed, and the steam injected through the pipe, in seeking to escape through the apertures in the funnel, dissolves the powder; the solution trickles to the bottom of the vessel at a temperature of 212°. At the termination of the process, a modicum of undissolved basic alum is left in the funnel, which is added to some concentrated liquor ready for precipitation by sulphate of potassa, and is redissolved as before stated. During the time the flour is dissolving in the roching vessel, the crystallizers are being prepared, and the aluminous solution, of a density about 1·485 to 1·515, is run into them by appropriate means.

These crystallizers are large wooden casks, five to eight feet high, three or four feet in diameter at the top, and tapering in a somewhat conical form towards the bottom. The staves of these casks are very strong, nicely adjusted, lined with sheet-lead, and held together by means of strong iron hoops, which are hammered on when required for use, and may be as easily removed.

Fig. 95 is a view of these casks arranged in the crystallizing shed, over each of which a spout is furnished for filling them with the liquor. Some of the casks are represented as on the point of being charged, while in others the crystallization is completed, and from which the staves are being taken off. When the casks are charged, they are covered up, each with its own lid. Being allowed to remain for four or five days, according to the state of the weather, the hoops are loosened and the staves removed; a crust of alum is formed, which is sufficiently strong to resist the pressure of the interior liquor. In this state they are left for a fortnight, in order to allow the whole of the crystallizable salt to form. The workmen then pierce a few holes in the sides of the column with an axe, so that the mother liquor in the interior may flow out into the gutters in the stone floor, which conduct it into an appropriate cistern, whence it is pumped up to dissolve fresh quantities of the prepared alum flour, and recrystallized as indicated. When the roching casks are dismantled, and the alum of the upper part removed, there is invariably found at the bottom a considerable quantity of white slime mixed with small octahedral crystals of alum. A quantity of this slime, well washed, gave the following centesimal composition:—

Fig. 94.



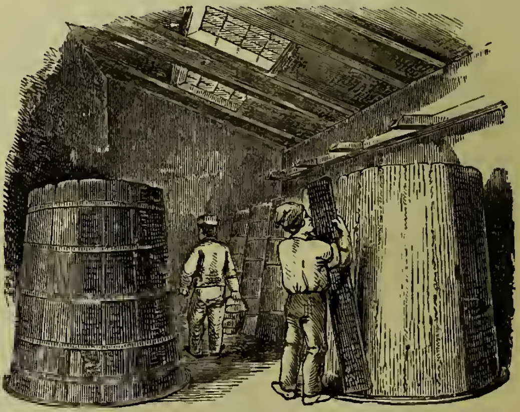
	Per Cent.
Sulphuric acid,	39·40
Alumina,	31·80
Potassa,	10·03
Moisture,	16·70
Insoluble matter,	2·07
	100·00

On examining the insoluble portion, it was found to contain

	Per Cent.
Silica,	73·79
Alumina, with a trace of iron,	21·83
Lime,	3·49
Loss,	·89
	100·00

The mother liquor which remains after the separation of the alum, is composed of solutions of sesquisulphate and protosulphate of iron, chlorides of iron, sulphate of magnesia, and alkaline sulphates; and when soap-boiler's waste has been used as the precipitating agent, it contains, in addition to the foregoing, soda alum in moderate quantities: if bisulphate of potassa, saturated with wood ashes, has been employed, the liquor will contain some sulphuric acid, and other ingredients, in small proportions. By knowing the nature of the alum shale, or ore, in the first instance, from a chemical analysis, a good idea can be formed of the principal bodies remaining in the mother liquor, and the subsequent application of it to the formation of secondary products; for instance, if free acid should be detected in the lie, it may be employed to neutralize crude carbonate of ammonia from the gas-works, to procure sulphate of ammonia; or, if much iron be present in the acid liquor, a further addition of borings of iron,

Fig. 95.

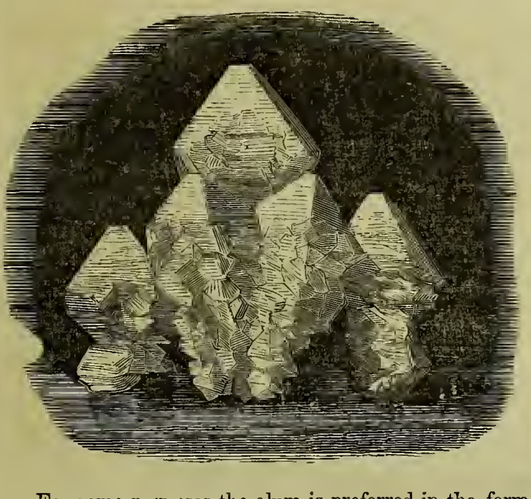


or old iron, is added, and in this way sulphate of iron for manufacturing purposes is formed. Should the mother liquor contain large quantities of the mixed chlorides of iron, it may be evaporated to dryness, and the dry mass heated to redness in a reverberatory furnace to drive off the hydrochloric acid, and thus sesquioxide of iron which may be used as a pigment is obtained.

Even sulphate of magnesia—Epsom salt—is manufactured from the mother liquors of the ores.

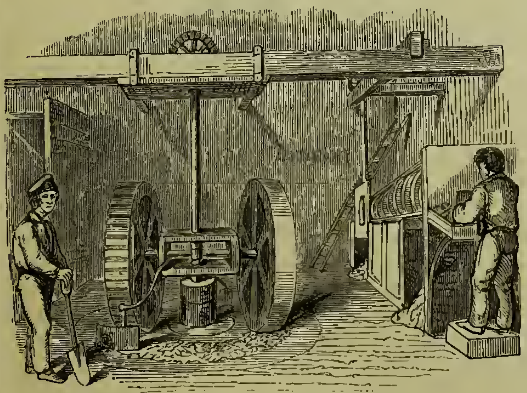
The mass of alum is cut into square blocks for market, when it will be found interiorly to consist of beautiful large octahedral crystals, similar to Fig. 96, which project from the sides and cover of the vessel.

Fig. 96.



For some purposes the alum is preferred in the form of a fine powder or flour, and in this state, therefore, a portion is prepared for the market. Fig. 97 is a sketch of the machinery usually employed at the alum-works for this purpose. The alum. reduced to coarse fragments, is crushed beneath a pair of ponderous wheels or rollers, of cast-iron, one of which is rough or fluted on the rim, and the other perfectly smooth. These traverse in a circle, and the alum is constantly pushed into the path of their revolution by two vertical revolving blades, one of which sweeps it inward, and the other outward. The grooved roller crushes the larger fragments before they are subjected to the action of the smooth surface of the other. When one charge is thus reduced to powder, it is shovelled out by an attendant to make room for a new supply; and the powder is passed by hand into a hollow cylindrical sieve, shown at the right hand of the figure. The lower portion, or belly of the cylinder, which lies in a slightly inclined position, consists of fine wire-gauze; the upper convexity is made of white-iron. This is surrounded by wooden hoops, to which are attached brushes that pass into the interior of the cylinder. An oscillating motion is given to the latter, and that portion of the alum powder which has been reduced to a state of sufficient fineness, is driven by the action of the brushes through the sieve, from which it falls in a beautiful white flour into a box below—the coarser particles passing onward to the other end of the cylinder, to be again subjected to the action of the crushing rollers. From one-tenth to one-eighth of the produce of the Scotch alum-works is sent to market in this form, in which it is easier of solution, and therefore more convenient for some of the numerous processes to which it is applied in the arts.

Fig. 97.



Production of Alum from Rocks containing Alumina.—Alum has been produced from various rocks of which alumina forms a constituent, by a process similar to that which naturally gives rise to this body in volcanic districts. The operation is confined to one or two isolated works on the Continent, and those are conducted in juxtaposition with metallurgic operations where sulphurous acid is in abundance. At Lintz, on the Rhine, where there is a spelter-work, and plenty of zincblende—sulphide of zinc—the sulphurous acid evolved during the roasting of the ore is conducted over the aluminous mineral moistened with water. Basalt and copper slate are the materials employed, and when these are exposed to the action of the gas, and sufficient moisture and air, decomposition ensues; sulphate of alumina, with sulphates of iron and copper, are formed, which are separated from the insoluble residue by steeping with water, and the subsequent treatment for obtaining the alum is on the same principle as those methods which have been already described. In such operations there is always a quantity of soda alum produced, on account of the presence of this alkali in the basaltic mineral. The soda alum is formed from the commencement, and the amount corresponds of course with that of the soda in the mineral, which in many basalt rocks is from five to six per cent.

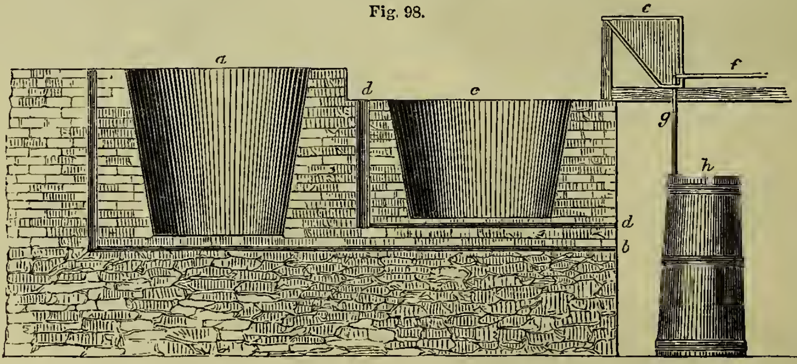
Alum from Clay.—Chaptal and Alban, in France, pursued a different course for the preparation of alum from clay. Clay consists of basic silicate of alumina, or silicate of alumina with free alumina, $Al_2 O_3 3 Si O_2 + Al_2 O_3 3 H O$ (?), and by the action of sulphuric acid, sulphate of alumina is formed with separation of silicic acid. Plastic or pipe-clay answers the purpose best; but that the acid may more readily penetrate the mass, the clay is submitted to a previous calcination to increase its porosity, and more fully oxidise the iron which it may contain. Fresh clay, when employed, requires a considerably longer time than when it is calcined and pulverised previously to the addition of the acid; if it be found requisite, the ground material is sifted. Forty-five per cent. of the weight of the clay of sulphuric acid, of 45° B., is poured upon it in a cistern which is heated, by the superabundant caloric from the calcining furnace, to about 158° Fahr. Decomposition ensues, and the mass assumes a greater consistency from the liberation of silicic acid; in this state the contents of the cistern are removed to the open air, where they are allowed to remain for a space of some months, to allow of the complete disintegration of the clay by the acid. The mass is afterwards lixiviated, and the sulphate of alumina treated as in ordinary cases. Clay, with as little iron and lime as possible, should be selected. Some manufacturers employ large shallow troughs, lined with lead, and heated from below by flues, for the purpose of mixing the prepared clay with sulphuric acid, in which it is frequently turned over until the acid has combined with its alumina. In this part of the operation an improvement has been lately effected, which consists of distributing the clay upon a shallow circular trough, and permitting the proper quantity of acid to flow in several small jets from a cistern placed above, while a rouser, worked by machinery, mixes the clay and acid thoroughly. In this way a more speedy combination is effected, than in the forementioned method. After the termination of the action of the acid, the contents of the cistern are removed to the stone pit, *a*, Fig. 98, where they are treated with successive quantities of water, to extract the sesquisulphate of alumina. Each lie is siphoned off into the pipes, *b b*, which convey it to the evaporating pans, to be boiled down to the proper strength for precipitating with the alkaline salt. When this point is attained, the liquor is pumped up into the stone pit, *c*, which is similar to *a*, already described, and called the precipitating vat; here the appropriate addition of sulphate of potassa is made. On agitating the solution, the *alum powder* precipitates; this is allowed to subside, and the mother liquor is drawn off to the pipes, *d d*, by a siphon. If the mother liquor be not very impure, it is employed for a subsequent precipitation. The precipitated alum is washed in the cistern, *c*, with successive small portions of water, each liquor being drawn off repeatedly in the same way as the mother liquor.

When the powder is purified by repeated washings, it is ladled out into the funnel-shaped vessel, *e*, where it is very economically dissolved, by injecting steam upon it through the pipe, *f*, and the saturated solution of alum descends to the crystallizing frame, *h*, through the pipe, *g*.

The evaporation of the various liquors is conducted in boilers lined with lead, by means of convoluted steam pipes placed in the liquid. This plan of concentration of the liquid is found to be best adapted for such liquors, as well as being cheaper.—*Knapp.*

Mr. Taylor, of Bristol, proceeds in making alums from pipe-clay, by calcining it in the usual way, and then treating it with its own weight of sulphuric acid, of specific gravity 1·200, in a large tub, upon the bottom of which a steam-pipe is coiled for the purpose of heating the mixture to about 200° or 212° Fahr., and some furnace clinkers and pieces of pottery, or other matters, are also strewed upon it to facilitate the filtration of the solution of sulphate of alumina. After the mixture of clay and acid has been heated for twelve hours, the solution is drawn off through a pipe at the bottom of the tube to the precipitating vats at a density of 1·300.

Fig. 98.



From Felspar.—This mineral, which is a double silicate of alumina and potassa—$Al_2 O_3 3 Si O_2 + K O Si O_2$—is decomposed by sulphate of potassa in a reverberatory furnace, and then fused with carbonate of potassa to a glass; on treating this with boiling water, decomposition follows, a soluble silicate of potassa dissolves, while an insoluble double silicate remains. The insoluble portion, when treated with boiling sulphuric acid, is decomposed into alum, and silica separates. The alum is dissolved out by water, and the solution evaporated for crystallization; the soluble alkaline silicate may be turned to account by combining the silica with lime.

Turner was the first to carry out the proposition of Sprengel, of converting felspar into alum. A patent was granted to him in 1842 for his process, which he describes in his specification as follows:—If desirous of making potassa alum, the best substance to operate upon is a potassa felspar. This felspar is ground in a common edgestone mill, till the powder is like fine sand, a process which is much assisted by heating it to redness, and then plunging it in cold water; it is afterwards mixed with its own weight of sulphate of potassa, and placed in the upper part of the inclined bed of a reverberatory furnace, similar to the annexed, Fig. 99 —known in the potteries as a *frit-furnace*—previously brought to a red heat. When the glass produced by the fusion of the powdered mineral and the alkaline sulphate has been observed to flow down to the bed of the furnace, there is added gradually, at the lower end of the furnace, as much carbonate of potassa as was previously used of sulphate. This operation of adding proportionate quantities of carbonate of potassa to the molten mass as it flows down into the lower part of the furnace, is continued till the *sack* of the furnace is quite full, the mineral and sulphate being introduced at the upper end: the glass is then fit for the next operation.

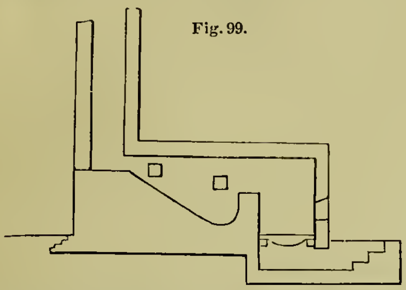


Fig. 99.

The compound might be prepared in a furnace with a flat bottom, from which it is separated with greater facility; in this case, however, no carbonate should be used till the whole of the sulphate has been observed to be decomposed, after which it is to be introduced, as in the preceding instance, and fused with the mass. On boiling the glass produced in this manner with water, the same quantity of potassa as was added to the felspar, and two-thirds of the silica contained in the mineral, are dissolved, while the remaining one-third of silica, and the alumina, and an equal quantity of potassa as the felspar originally contained, are left in the form of a light porous substance, similar in composition to elaolite, which is carefully separated from the solution, and washed well with water to withdraw silicate of potassa; next, the porous precipitate is put into a large leaden cistern or boiler, wherein it is acted upon with boiling dilute sulphuric acid, of specific gravity 1·20, which will contain sufficient water for the solution and crystallization of the alum formed by the decomposition of the elaolite. As a general rule, as much acid should be added in the diluted state as will contain one hundred and sixty pounds of dry acid to every two hundred and eighty-five pounds of felspar employed. If other minerals should be acted upon, a proportionate quantity of acid should likewise be used, that the solution of alum formed may not be impregnated with free sulphuric acid. To guard against the too great acidity of the solution, it is better not to add but one-fourth of the quantity of sulphuric acid to the elaolite formed in the first operation; part of the substance will remain undecomposed after the alum solution has been drawn off, but this may be acted upon by the whole of the remaining quantity of acid, and will be completely decomposed, and the liquor retained to act on a fresh batch. In the second operation, any free acid that had been left is neutralized, and a solution of alum from excess of acid is thus produced. The boiling menstruum, after the sediment subsides, is drawn into coolers, such as are generally used for crystallizing alum; here about four-fifths of the alum contained in the liquor will separate in crystals. From this mother liquor the residual alum is obtained by evaporating it to dryness; by this means the silica present in the solution is rendered insoluble, and the dry mass is acted upon either with water or a further quantity of mother liquor, and the solution evaporated to the crystallizing point as before.

Had soda salts been used in the above process, soda alum would be produced; but for this end albite is preferred, as it contains an excess of this alkali. The potassa or soda—as the case may be—which is extracted from the elaolite or nepheline—formed when soda is used—in the solution, is recovered by the following methods:—The strong solutions which are obtained, about the specific gravity of 1·20, are placed in any convenient vessel through which a stream of carbonic acid is transmitted; the carbonic acid is absorbed, and the solution assumes the appearance of a gelatinous mass from the separation of hydrated silicic acid; the liquid contains carbonate of soda or potassa.

On drying this mass in a furnace, which should never, under any circumstances, be allowed to rise to a red heat, the silica loses its water, and becomes insoluble; and by subsequent treatment of the dry residue with water, the alkali is dissolved out in the form of sesquicarbonate, which is obtained in the solid state by evaporation.

The second method, which is the simpler, is to filter the alkaline silicate through a bed of caustic lime, when it will be found that the lime has combined with the silica, and caustic alkaline lie passes through. An apparatus, similar to that of a soap-boiler for the preparation of his lies, may be used; and the alkali may be subsequently converted into carbonate, in the usual way of making soda ash.

With the exception of the high temperature required to decompose the felspar, **Turner's** process is very successful, but this was found to be a serious drawback when working on the large scale.

Telghmann has lately procured a patent for obtaining sulphate of potassa and chloride of potassium by acting on felspar, and by working on this principle in the manufacture of alum the impediment just mentioned might be overcome.

Alum may likewise be obtained by treating a mixture of two parts of felspar and three of fluorspar with sulphuric acid at a low red heat, until vapors of hydrofluosilicic acid cease to be evolved. The decomposition of the fluorspar by the sulphuric acid causes the liberation of hydrofluoric acid, and this in turn decomposes the silicates, combining with their silicic acid to form the evolved hydro-fluosilicic acid, as is seen in the annexed equation—

$$Al_2\,O_3\,3\,Si\,O_2 + K\,O\,Si\,O_2 + 12\,Ca\,F + 4\,H\,O\,S\,O_3 = \\ Al_2\,O_3\,3\,S\,O_3 + K\,O\,S\,O_3 + 12\,Ca\,O + 4\,H\,F,\,Si\,F_2.$$

Sulphate of lime is formed in the first stage of the process; but this is subsequently decomposed, and the sulphuric acid transferred to the alkali and alumina, as these bodies are deprived of their silica.

The mass is lixiviated with water, and after the separation of some sulphate of lime, the solution is evaporated, and on cooling it deposits an abundant crop of nearly pure alum crystals.

Mr. WILSON, of Glasgow, secured a patent in 1849 for the manufacture of alum by a new process, the chief advantage of which is stated to consist in the manner of heating the liquids for digesting the shale, and in applying the mother liquors after precipitating or separating the alum, so as to make the sulphuric acid, either free or in combination with other bodies, available in subsequent operations.

The first part of the patent process is an improvement upon the prevailing mode of digesting the shale with sulphuric acid diluted with water or mother lie, the liquor being poured on in the cold, and heat communicated afterwards to the digesting vessels, either by steam or the application of fire. He first warms the mixture of sulphuric acid and water in a separate vessel, and runs it into the digesting tank containing the calcined shale, at a temperature between 150° and 200° Fahr., as is deemed necessary, and then maintains the heat at the proper degree, by conducting the waste caloric from the furnace of the heating vessel below, through flues under and around the digesters. The patentee alleges that, by this arrangement and method of operation, considerable saving of fuel is effected, and that there is a more perfect and uniform digestion than by the old system, wherein it was impossible to obtain a proper and efficient temperature throughout the mass of shale.

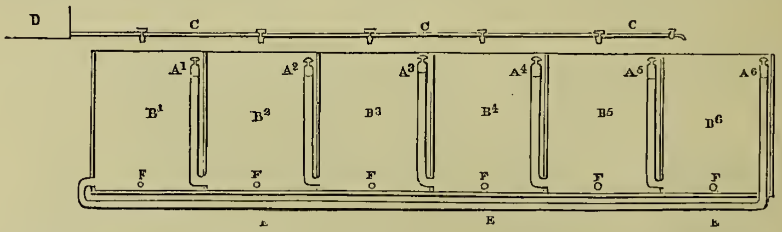
To prevent the loss of sulphuric acid, the ordinary method is varied in the following manner:—The strong mother liquors, left over after depositing the alum formed from the combination of the sulphate of alumina with the sulphate of ammonia, are not used again to dilute the acid, but are employed with fresh ammoniacal liquor from the gas-works, or elsewhere, to form sulphate of ammonia. He guards against the decomposition of the portion of alum which the mother liquor held in solution, by adding the ammoniacal liquor in such quantities, as that a slight portion of acid in the liquor is uncombined. A few trials would enable the operator to judge, by means of test papers, the proper point at which the neutralizing should be suspended.

When the solution of the mixture of sulphate of ammonia and alum, after filtration, or reposing to allow impurities to deposit, is sufficiently concentrated by evaporation, it is run in among the solution of sulphate of alumina from the digesters, and the alum which it contains is deposited with that of the fresh liquor.

WILSON also obtained a patent previous to the above, for manufacturing alum from the shale of the coal formation, which, however, scarcely differed from the usual method, excepting in the roasting of the ore. The plan, moreover, does not appear to have been successful.

RICHARDSON, in 1850, sealed a patent for further improvements in the manufacture of alum, the leading parts of which are as follow:—In lixiviating the calcined shale for the purpose of obtaining the raw alum liquor, a series of pits, such as is seen in the annexed figure, is employed. Fig. 100 shows the manner of effecting the solution of the sulphate of alumina.

Fig. 100.



B^1 B^2 B^3, *et cetera,* are a series of pits, furnished with pipes, A^1 A^2 A^3, *et cetera,* for the purpose of conveying mother liquor from one to another, the pipes being stopped with taps or cocks, as seen in the figure. Water is run from the service tank, D, through the pipe, C, into the pit, B^6, till it flows over through the pipe, A^6, and passes through the pipe, E E, till it enters B^1, through which it rises till the pit is filled, exhausting the contents of the soluble ingredients in its ascent. When the liquor has stood for some days, a fresh supply of water is continued as before in B^6, by which the liquor in B^1 is forced over through A^1, the plug being removed into the pit, B^2, containing fresh calcined shale; the liquor ascends through the shale in this pit as in B^1, and when it has remained two or three days in contact with it, a fresh supply of water is allowed to flow into B^6, which forces the liquid contents of B^2 into the third tank, and the treatment repeated as long as the workman finds it necessary, to bring the liquor to 28° Twaddle, or such higher strength as is required; and when the proper degree of saturation is attained, the solution is drawn off by the stopcock, F. As soon as the shale in any of the pits is found to be exhausted, it is removed, and a fresh supply introduced, and the lixiviation proceeded with as before.

Of course, as the operation goes on week after week, it will become necessary to commence the supply of water from the service tank, D, to the different pits in succession, which may be done as above described, or by allowing it to run at once down the pipes, A A A, from the respective taps in the pipe, C. By these arrangements, the labor of pumping the liquor from one pit to the other will be saved, the process generally rendered more convenient, and the result will be a more perfect exhaustion of the shale.

PRODUCE.—The great variation in the character and richness of the ores does not admit of even a proximate relation being established between the quantities employed, and the amounts of alum produced in different works. At Valmunster, from seventeen million three hundred thousand pounds weight of alum shale, four hundred thousand hundred-weight of alum, or 2·3 per cent., are obtained, for the production of which one hundred thousand pounds of sulphate of potassa are required, and one million four hundred thousand pounds of coal consumed.

The slate at Liege yields two per cent. of alum, and that from other localities only from one to one-half per cent.—*Knapp.*

PROPERTIES OF ALUM.—Potassa alum, when submitted to a heat of about 570° Fahr., fuses in its water of crystallization; the water being expelled during the fusion, the melted mass presents a pulverable white porous appearance, and is converted into anhydrous or burnt alum, which redissolves with difficulty in water; nevertheless, it absorbs its water of crystallization slowly from the air. At a red heat, the sulphuric acid of the sulphate of alumina is partly expelled in an anhydrous state, and partly as sulphurous acid and oxygen, while sulphate of potassa and alumina compose the residuum. Ammonia alum behaves in a similar way, but, after being heated to redness, only pure alumina remains; both varieties react acid on litmus paper. The composition of artificial alums has been made the subject of a chemical investigation by several chemists; a few of the results are given in the following analyses:—

POTASSA ALUM.

	Thomson.	Thenard.	Vauquelin.	Graham.	Theory.
Potassa,	9·86	10·02	10·40	—	9·95
Alumina,	11·09	12·53	10·50	54.11	10·83
Sulphuric acid,	32·85	26·04	30·52	—	33·71
Water,	46·20	51·41	48·58	45·89	45·51
	100·00	100·00	100·00	100·00	100·00

SODA ALUM.

	Wellner.	Ure.	Zellner.	Graham.	Theory.
Soda,	6·29	6·48	6·67	—	6·80
Alumina,	10·19	10·75	11·00	52·53	11·21
Sulphuric acid,	35·10	34·00	34·32	—	34·89
Water,	48·22	49·00	48·01	47·47	47·10
	99·80	100·23	100·00	100·00	100·00

AMMONIA ALUM.

	Riffault.	Forchhammer.	Theoretical.
Ammonia,	—	—	3·75
Alumina,	11·906	11·24	11·34
Sulphuric acid,	36·042	35·90	35·29
Water,	—	—	49·62
			100·00

CHINESE ALUM RECENTLY IMPORTED INTO THIS COUNTRY.

	Richardson.
Sulphuric acid,	34·06
Alumina,	11·38
Potassa,	10·44
Water,	43·12
Loss,	1·00
	100·00

IMPURITIES.—The purest kinds of alum always contain a little iron; that from Liege contains 0·02 per cent.; that from Gavelle, near Paris, 0·08 per cent.; that from Aveiron, 0·11 per cent.; and English alum contains 0·12 per cent. This admixture of iron alum, which is easily detected by ferrocyanide of potassium, is sufficient to impair the delicate colors imprinted upon cloth; it can, however, be removed by recrystallization, or, as prussian blue, by means of yellow prussiate of potassa. Only the Roman alums—a name given to all varieties of alum imported from Italy—are sufficiently pure for immediate use, and are highly prized on account of the minuteness of the quantity of iron which they contain, although their outward appearance would naturally lead to the contrary assumption.

These varieties consist of small disconnected crystals, covered externally with a kind of reddish mud, which is stated by some to be void of iron; on the alum being dissolved, however, in water, none of this coating is acted upon, and the quantity of iron alum present in the solution, does not exceed 0·005 per cent. Alum of this description produces a blue precipitate, with the aforementioned reagent, only after standing several hours, while ordinary alum affords a precipitate in a few minutes. Roman alum is generally crystallized in the form of octahedrons, but cubical crystals are occasionally found, hence the name *cubic alum.* The composition of Roman alum, and the circumstances which occur during its formation, have not been minutely investigated; its reactions differ from ordinary alum in many respects. When the cubical crystals of Roman alum are dissolved in water, at a temperature ranging between 96° and 104° Fahr., and the solution is set aside to crystallize, the alum is again produced in cubes, which appear more certainly if the liquor be left to spontaneous evaporation. At a higher temperature, the solution becomes turbid from the separation of basic alum, and the clear liquor deposits the substance in octahedral crystals: hence it may be inferred, that the Roman cubic alum is formed in the presence of an excess of alumina in the crystallizing alum liquor. When octahedral alum is digested with hydrated alumina, and the solution allowed to evaporate spontaneously by exposure, cubical crystals are formed with a simultaneous separation of a basic salt of alumina; the crystals have an acid reaction, and the same properties as ordinary octahedral alum.

In a paper recently communicated to the Parisian Academy of Sciences, by M. LOEWEL, upon the identity of octahedral and cubical alum, and the production of the latter, the author remarks, that on account of cubic alum being regarded as a basic salt, and as containing more alumina than the ordinary octahedral alum, he was induced to institute the experiments of which the following is an epitome:—

The idea of cubic alum containing more alumina, arose from the fact that in making alum in the ordinary way, by dissolving the materials in water, its solutions never deposit cubic crystals, neither by cooling nor by spontaneous evaporation, unless hydrate of alumina has been previously dissolved in them, or a certain quantity of an alkaline base has been added to withdraw from the sulphate of alumina a part of its acid. All the chemical treatises state, notwithstanding the preceding opinions among chemists and manufacturers, and very apropos, that dimorphous crystals have the same composition; definite proof has not, apparently, hitherto substantiated the proposition, and without this, such statements are in open contradiction to the observed phenomena that cubic alum, when dissolved in water, and recrystallized under the octahedral form, deposited a certain quantity of basic sulphate of alumina.

Having submitted the salts in question to a chemical examination, LOEWEL obtained results which seem to dissipate all doubts upon this point. He prepared, in the usual manner, *pure* potassa and ammonia alums, and crystallized under the ordinary octahedral system. During this part of his labors, he states that, in many of the alums of commerce, the sulphate of potassa in the alum is partly replaced by sulphate of ammonia, but the proportionate quantity of the latter is very variable.

To obtain the cubic crystals of alum, the pure substance stated above was dissolved in three or four times its weight of water, heated from 72° to 81° Fahr., and an aqueous solution of potassa in alcohol added in successive small portions, till the subsalt of alumina, thrown down by each addition, was no longer dissolved upon the agitation of the liquid

Cubical ammonia alum was procured by dissolving the pure octahedral salt which had been prepared in three to four times its weight of water at 113° Fahr., and adding ammonia with the same precautions as the potassa in the preceding instance, till the small quantity of subsalt ceased to dissolve in the solution. The spontaneous evaporation of the potassa and ammonia alum solutions, at the ordinary temperature, afforded the crystals in cubes. The author, however, observed, that in some of the operations performed, the first crystals deposited were still octahedrons, while, in others, they assumed, after the lapse of some days, the form of beautiful transparent perfect cubes; and lastly, other solutions became ambiguous, and showed a cloudy appearance before depositing the crystals.

The form assumed by the salt after adding a quantity of potassa—representing about one equivalent and a half, that is, on taking from the sulphate of alumina contained in the alum nearly the half of its acid—was that of truncated and cubical octahedrons; but on a further addition of a little alkali, cubes were formed.

When the potassa solution was added by very small portions at a time, and with much precaution, it was found that a quantity representing nearly one equivalent and three-quarters, might be introduced before obtaining a precipitate which no longer completely dissolved by long agitation of the liquid; such solutions, however, though quite clear after being filtered, became cloudy after some time before depositing crystals.

It appears from the preceding, that it is necessary to abstract at least one-half of the acid contained in the sulphate of alumina in the alum, before the crystals are obtained in cubes. When some of the solutions thus prepared had given a certain quantity of cubic crystals, but not nearly the amount of that contained in the liquid, the solution then became cloudy by degrees, and deposited a gelatinous tribasic sulphate of alumina. The alum subjected to the experiments afterwards to be described, was taken from the mother liquors before they became cloudy, in small beautiful transparent crystals, of from half to one inch in the length of the sides: the crystals were washed and dried before each experiment.

On dissolving the two salts in water, perfectly clear menstrua were obtained, which remained so even during their concentration, and furnished, on cooling, truncated octahedrons. The cold solutions of the salt, even without concentration, afforded a like result. The octahedral alum salt procured in this way had exactly the same weight of alum as was dissolved of the cubic alum, without a vestige of basic salt separating during the operations. Many who experimented on cubic alum, and stated that a portion of basic salt was thrown down, must have employed large opaque crystals obtained in the clouded solutions, and in this case the basic salt was simply interposed, and formed no integral part of the crystals.

The potassa and ammonia cubic alum described were found to resist the action of air dried by sulphuric acid in a bell-jar for weeks without efflorescing, although, in all chemical treatises, it is said that alum effloresces very slowly in the air. LOEWEL suggests that it would be more correct to state that no efflorescence takes place. He placed crystals of pure alum under bell-jars, in which the air was dried by sulphuric acid; at first the crystals lost some thousandths of their weight of interposed water, but afterwards remained for several months, even for a whole year, at a temperature rising to 77° Fahr., without parting with the smallest quantity of water.

The small cubic crystals were exposed several hours to a temperature from 158° to 185° Fahr., and then to 212° Fahr.; after a while the heat was raised more and more, to about 680° Fahr.; the total loss in water amounted to 45·5 per cent. Corresponding results were obtained by treating, in a similar manner, small octahedrons of the pure salt; hence, the alum under both forms contains exactly the same per centage of water of crystallization. The method of expelling the water pursued, as in the foregoing, was found to answer exceedingly well, inasmuch as, by such an application of the heat, the aqueous fusion, and consequent intumescence, were avoided.

During the drying it was observed that the crystals effloresced, and became a little agglutinated, losing at the same time, in a slight degree, their crystalline form, but without intumescence.

The sulphuric acid which the alum contained was determined by precipitating its boiling solution with an excess of chloride of barium in the usual way.

The annexed analyses show the correspondence of the sulphuric acid obtained in three experiments, with the calculated amount:—

			Found.		
Composition.	Atomic weight.	Theory.	I.	II.	III.
4 Eqs. of sulphuric acid,...	160 ..	33·72 ..	33·92	33·62	33·88
1 Eq. of alumina,........	52 ..	10·83 ..	—	—	—
1 Eq. of potassa,.........	47 ..	9·93 ..	—	—	—
24 Eqs. of water,..........	216 ..	45·52 ..	45·5	—	—
	475	100·00			

Hence, it is evident that the salt contains the same number of equivalents of sulphuric acid as ordinary alum crystallized in octahedrons.

The determination of the acid in the ammonia salt was conducted as in the analysis of the potassa; the alumina was ascertained by the total decomposition of the salt by heat, in the following manner:—After the alum had lost about 47 per cent. of its weight, the small capsule of platinum wherein the salt was weighed, was enclosed in a platinum crucible, and this again enveloped in a hessian one, which was surrounded with incandescent coals in a furnace, mounted with a chimney of plate-iron.

When at a very intense heat, the salt no longer lost in weight; on reweighing the crucible, the content of alumina was obtained.

The subjoined are the analyses of the ammonia alum, which agree closely with theory:—

Composition.	At. weight.	Centesimally represented.			
			Found.		
		Theory.	I.	II.	III.
4 Eqs. of sulphuric acid,	160	35·29	35·34	35·18	35·27
1 Eq. of alumina,	52	11·34	11·57	11·45	11·5
1 Eq. of ammonia,	26	5·73	—	—	—
24 Eqs. of water,	216	47·64	—	—	—
	454	100·00			

Octahedral crystals of the same salt were submitted to decomposition by heat, and the analysis agreed in every point with the preceding.

Loewel defines the circumstance which gives rise to the deposition of cubic alums, as being the effect of an action of contact exercised over its molecules by the solution of aluminated alum, in the midst of which it is formed and slowly deposited.

Neutral Alum.—This kind is much preferred in many arts where alum is employed, and especially among the printers of fabrics, on account of the greater amount of basic salt which it deposits than the ordinary substance, from which it differs only in not containing free acid.

To prepare it, alumina is often added to ordinary alum; a better method is to abstract the free acid by adding an alkali, such as carbonate of soda, or carbonate of potassa, to a solution of ordinary alum, as long as the precipitate which appears at first is redissolved. This affords the *neutral alum*, which is essentially a solution of ordinary alum, with a certain proportion of basic sulphate of alumina.

Commercial Sulphate of Alumina.—It has been stated that the presence of an alkaline sulphate is not essential in those processes in which alum is employed; it is, indeed, rather objectionable than otherwise. A substance has recently been introduced into commerce under the name of alum, which is very much more efficacious than the crystalline salt; it occurs in four-sided plates about an inch in thickness, which are white and partially translucent, dissolve perfectly in water, exhibit no trace of crystallization, and possess the peculiar taste of alum in a more marked degree than even alum itself. This substance is entirely free from iron. The process for its preparation, and for which Wiesmann has taken a patent, consists in treating clay with sulphuric acid in the manner before described; and differs only in adding no sulphate of potassa to the solution of sulphate of alumina, but precipitating any iron that may be present by adding ferrocyanide of potassium, evaporating to the consistence at which the mass will solidify when cold, and then pouring it into the *melting vessel.* Mohr found this substance, which is improperly called alum, to be perfectly free from iron, and to contain

Alumina,	13·91
Sulphuric acid,	36.24
Water,	49·60
Sulphate of potassa,	1·50

The latter ingredient is due to the small portion of potassa naturally existing in all clays. The preceding composition corresponds exactly with the combinations of

7·1 per cent. of ordinary potassa alum, and
92·9 " of sesquisulphate of alumina.
The formula of which is $Al_2 O_3 3 S O_3 + 18$ aq.

A sample of this preparation from the Morley Works, near Plympton, which was analysed by the Editor, gave the annexed quantities of the respective ingredients:—

	Centesimally represented.
Alumina,	17·820
Sulphuric acid,	33·178
Water,	49·002
Lime,	a mere trace.
	100·000

These numbers correspond with the formula,

$$2 Al_2 O_3, 5 S O_3 + 33 \text{ aq};$$

thus showing it to be a basic sulphate.

The objection which manufacturers urge against this compound is, that from its physical appearance it is impossible to judge of its purity in the same way as common alum.

Wiesmann's process for the preparation of pure sesquisulphate of alumina has been found the most effectual and economical; it consists in agitating the solution of sulphate of alumina in a large wooden vessel with ferrocyanide of potassium.

The vessel wherein the mixture is made is similar to A, in Fig. 101. After allowing the bulk of the precipitated prussian blue to subside, the supernatant liquor is run off into the wooden vessels, B B B, where it remains until perfectly clear and free from precipitate, after which the clear liquor is treated as has been already described.

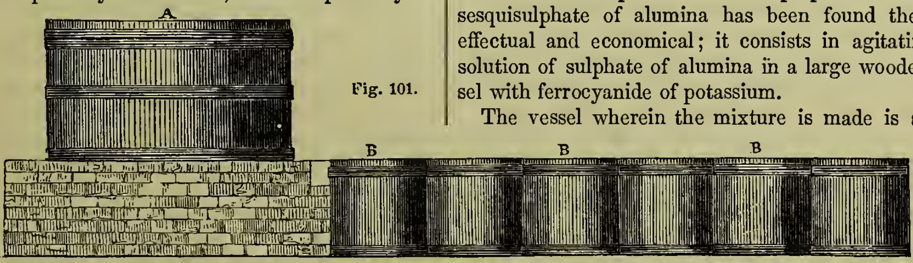


Fig. 101.

The precipitated prussian blue is repeatedly washed with cold water to separate the whole of the sulphate of alumina, and the solutions are drawn off into some of the vessels, B, for the above object.

The prussian blue is now treated with a lie of caustic soda to separate the iron, and thus the same precipitant serves for a longer period with very little loss.

Richardson's analysis of this sulphate, after the iron had been separated by the above process, is—

Sulphuric acid,	35·95
Alumina,	14·25
Lime,	traces
Magnesia,	traces
Chlorine,	traces
Water,	48·05
Loss,	1·75
	100·00

When the crude sulphate of alumina is lixiviated, there remains a refuse matter that contains some sulphuric acid in the form probably of subsulphate, and which resists the solvent action of water.

Two samples of this residuary matter gave the annexed results:—

Silica,	41·85	39·05
Alumina, with traces of sesquioxide of iron,	18·40	25·55
Sulphuric acid,	4·45	8·47
Sulphate of lime,	4·01	traces
Water,	29·53	27·50
Loss,	1·76	—
	100·00	100·57

The Editor has been informed by several of the first manufacturers—those at Whitby in Yorkshire, and Hurlet, near Glasgow—that during the few last years the alum trade has been so depressed that the produce scarcely balanced the expenditure, owing partly to an unwise competition; and that many makers would have ceased operations, but having the works on hand, free of other expenses, exclusive of the labor, it was thought advisable to continue them. In the market, alum commanded only eight pounds per ton during the last year, but at present the price is from ten pounds to ten guineas, and at this rate promises a remuneration.

A proper and reliable estimate of the quantity of alum fabricated cannot well be made, since it is an article which affords no convenient means for ascertaining it—being free of duty—except by consulting the note-books of all the manufacturers, an inspection which would, on private grounds, and perhaps with reason, be refused. On an average, the quantity manufactured may be computed to be at least about ten thousand tons annually, of which there is reason to believe from four to five thousand tons are manufactured in Scotland.

USES.—This salt is largely employed in the arts, chiefly in consequence of the affinity which alumina, its primary base, has for coloring and other vegetal matters; for gelatine, and a number of like bodies. The fibre of cotton, wool, *et cetera*, has such an affinity for alumina, or a basic salt of the base, that when immersed in a solution of alum, a basic salt adheres to it so firmly that it cannot be removed by washing.

This basing with aluminous salts, enables the cloth to unite with larger quantities of the coloring matter, and retain it with greater persistency. Some precautions are to be observed in its use in the hands of the cloth printer, which will not here be entered into, as they will form a part of the subject to be treated of, in a future part of this work, under CALICO-PRINTING.

Alum is used in preparing white leather, called *tawing;* to clarify water, by the combinations which it forms with the foreign matters present, and also in the preparation of bookbinder's paste. A large quantity of alum is taken medicinally, as a topical and internal remedy in various diseases. Alum mixed with gypsum —sulphate of lime—forms the chief ingredient with which the outer chambers of MILNER'S fire-resisting safes are lined, so as to protect the interior depositories from being injured. This it does from two causes: firstly, the large quantity of water it contains, which helps to moisten the inner chamber when the box is heated, and so prevents the contents from being consumed; and secondly, from the non-conducting power of the mixture after the water is expelled.

A better salt could not have been patented for this purpose, and the great success which has attended the application is the best testimony to its efficiency.

Alum is the compound employed for preparing most of the salts of alumina, particularly red liquor, already described at page 36.

ALUMINA.—This is the base of the alums, which contain sesquisulphate of alumina as one of their constituents, and the utility of alum in calico-printing rests solely upon this earth. Alumina is likewise extensively used, united with silica, in the manufacture of all kinds of earthen and porcelain ware; in the manufacture of crucibles, mortars, and cements. It is particularly employed, almost in its purity, for the manufacture of *glass pots*, where the refractory power of the earth is such as to permit the fusion of the *frit* while they remain unaltered, either by the intense heat, or by the molten substances.

Alumina occurs on the surface of the earth in a pure state only in some rare minerals—for example, the corundum, the sapphire, and the ruby; but it constitutes a large proportion of all the slaty and shaly rocks. It is the main ingredient also of pipe-clay and argillaceous soils, which increase in tenacity in proportion to the quantity of alumina they contain.

Though it exists so largely in the soil, it contributes but little in a direct manner to the *nourishment* of plants, as the ash they leave contains, in general, *a very small quantity* of alumina.

Preparation.—Alumina may be precipitated from any of its solutions by an alkali, as a bulky, white, amorphous powder, which, when collected, well washed, and dried, is pure. It is a white, tasteless, earthy substance, adheres to the tongue, has a specific gravity of 2·00, and is insoluble in water, but dissolves easily in caustic potassa and soda, and in most acids, at least when newly thrown down. When heated to redness, however, it becomes hard and dense, as in burned clay and firebricks, and can then only be dissolved with extreme difficulty, even by the strongest acids.

In combination with phosphoric acid, alumina forms one compound well known to mineralogists, by the name of *wavelite*, which occurs, however, in too small a quantity to be an object of interest to the manufacturer.

One of the most difficult problems in analytical chemistry, is to effect a perfect separation of a small proportion of phosphoric acid from alumina, and rigorously to estimate its quantity; hence, in the greater part of the analyses of soils hitherto published, this most important ingredient in a fertile soil—phosphoric acid—when in combination with alumina, has either been altogether neglected, rudely guessed at, or indicated only by a rough approximation. There is no direct proof, therefore, of the extent to which the phosphates of alumina exist in different soils.

Alum has not been extensively tried as a manure. Its composition, however, would lead one to expect it to exert a beneficial influence on the growth of many roots, especially turnips. SPRENGEL has experimented with it, and considers it worthy the attention of agriculturists.

AMMONIA.—*Ammoniaque*, French; *Ammoniak*, German.—In the gaseous state, ammonia is synonymous with the *alkaline air* of PRIESTLEY, *volatile alkali, et cetera;* in the liquid state, with the caustic spirit of sal-ammoniac.

Gaseous ammonia was probably known to the ancients, though no record of the fact remains to prove it; still, as the manufacture of ammoniacal salts was a source of trade among the Egyptians, it is very probable the pungency of the gas was familiar to them. The scientific development of this compound remained for Dr. BLACK, who, in 1756, first isolated it, and proved its distinction from the sesquicarbonate of this base; PRIESTLEY afterwards, with greater accuracy, in a more lengthened investigation, prepared it in a pure state, and discovered more of its properties.

Ammonia, though not very extensively disseminated in nature, is to be met with in a great many vegetal products; the decomposition of animal matter, either by putrefactive fermentation or destructive distillation, yields it in moderate abundance; it is also found united with acids in many strata of the mineral kingdom. In the atmosphere, very minute portions of ammonia are present, which exert a most beneficial influence upon vegetation. Volcanic districts are highly productive of ammonia, standing second in this respect only to the guano islands of South Africa. Sea water contains a low decimal per centage of ammoniacal salts; fresh water also holds it in combination, but in an infinitesimal proportion. A perceptible quantity of this alkali, generally combined with acids, is found in mineral springs; soils almost universally contain it—more especially, however, those of the ferruginous and argillaceous class. In many substances where ammonia is apparently absent, a careful and patient investigation may prove its presence; and often where it is detected unexpectedly, it is precipitately judged that its formation may be owing to the unusual direct combination of hydrogen with the nitrogen of the atmosphere, whereas a calm and considerate review of the materials, and of the circumstances attending such operations, may lead to a more simple and conclusive demonstration of its presence. Thus, it occurs in the atmosphere; apparently no ammonia exists in it when performing an analysis, but on examining rain water recently collected in town or country, an expert chemist will detect it in minute quantity.

Animal recrements, especially those of reptiles, are rich in ammoniacal compounds.

Preparation.—It may be prepared in the laboratory by a very simple process, and one which is familiar to every student in chemistry; namely, by heating an ammoniacal salt with hydrate of lime in a retort, and collecting the eliminated alkaline vapor over mercury, or by displacement of air. This operation, though simple, requires—like all those conducted on the small scale—care and skill, to obtain a pure product. The decomposition which takes place in the preceding instance, supposing that chloride of ammonium had been employed, is the following:—

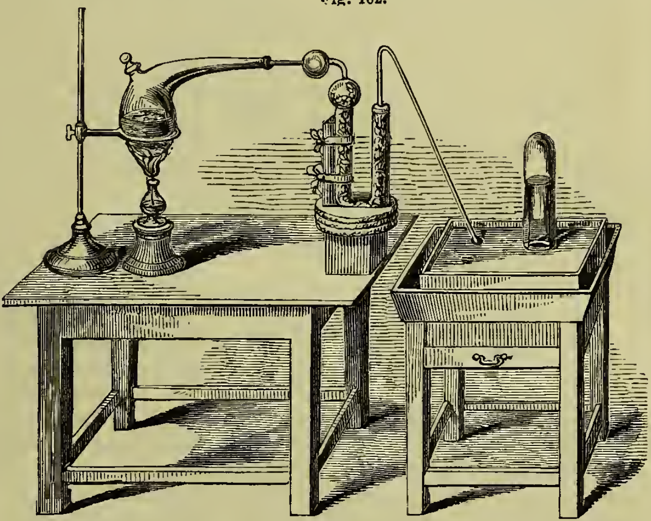
$$\underbrace{\mathrm{N\,H_4\,Cl}}_{\text{Chloride of ammonium.}} + \underbrace{\mathrm{Ca\,O\,H\,O}}_{\text{Hydrate of lime.}} = \underbrace{\mathrm{N\,H_4\,O}}_{\text{Ammonia.}} + \underbrace{\mathrm{Ca\,Cl} + \mathrm{H\,O}}_{\text{Chloride of calcium and water.}}$$

By desiccating the $\mathrm{N\,H_4\,O}$ over lime, previous to its reaching the mercurial trough, an atom of water is withdrawn, and the gas which enters the jar has the constitution represented in the annexed equation—

$$\underbrace{\mathrm{Ca\,O}}_{\text{Lime.}} + \underbrace{\mathrm{N\,H_4\,O}}_{\text{Ammonia.}} = \underbrace{\mathrm{N\,H_3}}_{\text{Ammoniacal gas.}} + \underbrace{\mathrm{H\,O,\,Ca\,O}}_{\text{Hydrate of lime.}}$$

The arrangement in Fig. 102 is well adapted for the preparation of ammoniacal gas: equal weights of the chloride of ammonium and hydrate of lime are intimately mixed, and introduced into the retort; heat is applied, gently at first, and then gradually increased till vapor ceases to be evolved—chloride of calcium remains.

Fig. 102.



In a chemical point of view, ammonia is generated in various and curious ways; as, when an excess of hydrogen is burned in the atmosphere, nitrate of ammonia is formed; when iron oxidizes, from the decomposition of water, sesquioxide of iron and ammonia result. A similar combination is formed when hydrate of potassa, soda, baryta, or lime, is heated in the air, or in hydrogen, with iron, zinc, lead, tin, or arsenic. REISET explains its formation in hydrogen as arising from nitric oxide—deutoxide of nitrogen—derived from the sulphuric acid used to prepare the hydrogen, and adduces as a corroboration the fact, that when iron filings are heated in a strong solution of potassa to 266° Fahr., they evolve hydrogen and ammonia, both when heated in air, and in hydrogen containing nitric acid, but not in pure hydrogen. When nitrous oxide and an excess of hydrogen are transmitted over platinum black—spongy platinum—in the cold, no ammonia is formed; but if heat be applied, it is produced in considerable quantity. A dilute solution of nitro-sulphuric acid—composed of a hundred volumes of water, four and a half of sulphuric acid, and four of nitric acid—dissolves iron, zinc, or tin, without giving off nitric oxide, or hydrogen, although these bodies always result from the decomposition of nitric acid and the solution of the forementioned metals. In this instance, the hydrogen evolved from the solution of the metal combines with the nitrogen of the nitric oxide, and gives rise to the alkali.

Ammonia is a volatile, irrespirable gas, though, when diluted with air, it may be inhaled. Its odor is extremely pungent; it possesses a strong alkaline taste; turns reddened litmus paper blue, and turmeric paper brown; is very slightly inflammable, and extinguishes those bodies which are in a state of combustion. It is composed of two volumes of nitrogen and six of hydrogen, condensed into four volumes of the gas. The specific gravity of the vapor is ·5890, air being taken as unity.

By a pressure of six and a half atmospheres, at the ordinary temperature, it is condensed into a transparent colorless liquid, of 0·731 specific gravity at 60°; a like result is obtained at the ordinary pressure of the atmosphere, by reducing the temperature 40° below zero. It is a very subtle, colorless liquid, which, according to FARADAY, freezes into a white translucent crystalline substance at —103° Fahr. On heating one volume of the liquid to 60°, at a barometric pressure of 30·2 inches, it formed 1009·8 volumes of the vapor.

BERTHOLLET states that ammoniacal gas is composed of—

	Atomic weight.	Theory.	Berthollet.
1 Eq. of nitrogen,......	14	82·35	81·13
3 Eq. of hydrogen,.....	3	17·65	18·87
1 Eq. of ammonia,......	17	100·00	100·00

Ammonia is decomposed with facility by heat in the presence of a body which contains oxygen that is not difficultly transferable; hence, if the higher oxidized compounds of nitrogen be brought into contact with ammonia, and both compounds are mutually decomposed, water and a lower oxide, with the occasional elimination of nitrogen, are the result. When transmitted over many metallic oxides at a dull red heat, it is decomposed into nitrogen and hydrogen; the latter abstracting oxygen from the oxide and forming water. The most interesting change, however, is that which produces cyanogen, and this, uniting with undecomposed vapor, produces cyanide of ammonium, while hydrogen is set free; it is effected by transmitting the ammoniacal gas over heated charcoal. The accompanying formula serves to explain the action :—

$$\underbrace{2\,N\,H_3}_{\text{Ammoniacal gas.}} + \underbrace{C_2}_{\text{Carbon.}} = \underbrace{N\,H_4\,C_2\,N}_{\text{Cyanide of ammonium.}} + \underbrace{H_2}_{\text{Hydrogen.}}$$

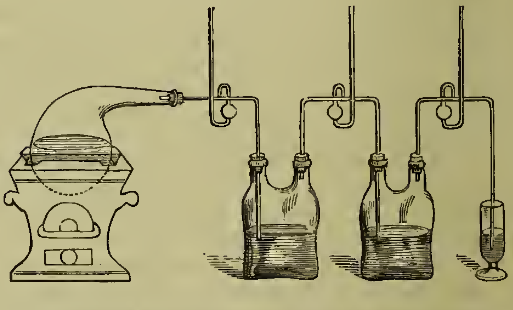
In point of utility, the gas possesses but little interest.

LIQUID AMMONIA.—*Salmiakgeist*, German; *esprit de sal ammoniac*, French; synonymous with *caustic ammonia*, and *spirit of hartshorn.*—The preparation of liquid ammonia is one among the many manufactures which have sprung up in consequence of the rapid progress of science and art during the last half century; but it seems to have risen to its present state simultaneously with that of gas-lighting. Considerable quantities of crude liquor ammonia are produced as one of the by-products of the distillation of coal; hence, within the last twenty-five years, the establishment of factories for the preparation of ammonia and its salts has gradually taken place, from the metropolis to almost every provincial village where gas is consumed. The demand for animal charcoal opened another extensive supply of ammonia, for it is evolved during the destructive distillation of the bones from which the animal charcoal is prepared for the sugar refiner and others; and as soon as the spirit of enterprise and emolument induced the capitalist to turn his attention to the manufacture, various other sources were discovered which yielded this alkali. The principle on which ammonia is generated on the large scale, differs in nothing from the processes already stated; and the formation of the solution of the alkali rests upon the property which water possesses of absorbing it. Water, at a temperature of 50° Fahr., condenses about six hundred and seventy times its bulk of ammoniacal gas—seven hundred and eighty according to THOMSON; by this retention the bulk of the solution is increased considerably—so much so, that six volumes of water, on becoming saturated with the gas, increase to ten volumes, and the specific gravity of the liquid is reduced from 1·00 to 0·785.

Liquor ammonia is prepared in the laboratory by taking a mixture, such as that before prescribed, and introducing it into a glass or earthenware retort, the neck of which is connected with a series of Woulfe's bottles, nearly filled with water, as described at page 73. It is necessary that the lime used should be slaked in about four parts of water, previous to its being mixed with the powdered ammoniacal salt, as by that means the ammonia will be more freely disengaged, and with less heat than when only a small quantity of moisture is present.

Fig. 103 is a representation of an apparatus which answers the purpose remarkably well.

Fig. 103.



During the decomposition, the heat should not be too briskly applied, and in no case should the bottom of the retort be raised to redness, as portions of the salt would be sublimed without being decomposed; and, by passing over to the first bottle, would render its contents unfit for use. To guard as much as possible against the sublimation of the salt, the tube connecting the retort and first bottle should have a considerable calibre; and it is often advantageous to append a large bulb or balloon between the mouth of the retort and first condenser, in order that any portion of the sublimed salt which might be driven off towards the end of the operation, may be arrested before it is carried into the ammoniacal liquor. The greatest precaution is to be taken in having all the connections air-tight, to prevent the escape of vapor. When the whole of the ammonia is driven off, it is necessary to raise the temperature a little higher than usual to fuse the chloride of calcium; and as soon as this takes place, the retort should be disjoined from the condensing bottles, and the fused salt poured out as speedily as possible. Very often the retort breaks at this part of the operation, in consequence of a layer of the salt solidifying upon its neck, which, on being exposed to the air readily absorbs moisture, and partly dissolves; the solution thus formed cools considerably, and on penetrating through the undissolved portion of chloride of calcium to the retort, which still retains a high degree of heat, the particles with which it comes in contact are suddenly contracted, and the retort cracks. Should the retort escape fracture at this part of the process, it generally happens that it is broken when heat is applied for a second operation; hence it is rare to find a retort, even when carefully handled, that will stand two operations. Lest any of the undecomposed salt may be eliminated, it is best to use only a small quantity of liquid in the first receiver, and return the product into the retort upon a second operation; the contents of the second and third bottles should be retained as pure.

Uses of Ammonia.—Ammonia is in daily requisition as a reagent for the analytical chemist. It offers peculiar facilities in the preparation of many compounds on account of its great volatility, as also that of its salts, and as being an almost universal precipitant of the oxides of the heavy metals. In medicine, ammonia is used to a moderate extent to alleviate spasms, for rousing the vascular and respiratory system, as an antacid, and in various other cases. It is extensively employed in bleaching and calico-printing, in color manufactories, and other important trades.

When ammonia is manufactured on the large scale from ammoniacal salts, the sulphate of the alkali is for the most part preferred; but there is no material deviation from the directions already laid down, except that another kind of apparatus is used, to avoid the loss of retorts which is incurred when preparing it in the laboratory. It is particularly necessary, when working upon the large scale with condensers in the form of Woulfe's bottles, to have the joints well luted; this is effected by covering each connection with a paste made of white of egg and chalk intimately ground. A better composition is produced by blending wax, resin, and turpentine together; this should be applied upon the connection of the tubes and tubulures of the condensers in moderate thickness. If this point is not attended to with care, the pressure upon the gas forces it through into the atmosphere, causing the workmen considerable annoyance till arrested.

Fig. 104 is a vertical section of an apparatus which answers well for the preparation of ammonia on a large scale.

A is an iron retort, placed in sand, over the fire *g*, of which *h* is the ash-pit, and *x* the chimney; *a* is the stopper, and *b* an iron pipe connected to the neck of the retort, and reaching some distance from the furnace to the end of the tube, *c*, which may be either of glass or lead. B is the first condensing vessel, and is supplied with three tubulures, through the middle one of which a safety tube is inserted. *e* is a stopcock and pipe, by which the contents of B are drawn off when requisite. This vessel is left nearly empty, for the purpose of purifying the gas of any traces of ammoniacal salt which may be carried over, and also for retaining traces of oily matters which are invariably present, either from the impurity of the salt employed, or from the grease with which the stopper is besmeared to prevent it from adhering too tightly in its place. B is connected with other condensers, of which only one, C, is seen in the figure; these vessels are filled to about three-fourths of their capacity with water, and so rapid is the absorption of the gas, that scarcely a trace of ammonia escapes from C, till the solution contained in it is completely saturated.

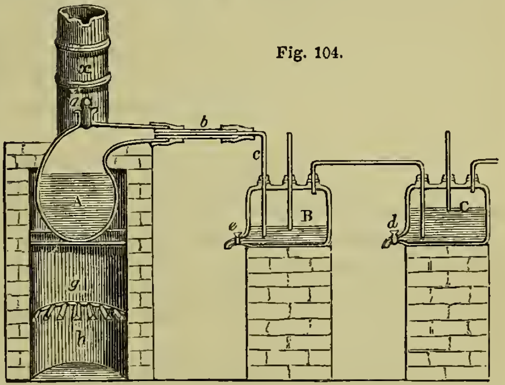


Fig. 104.

When this happens, the solution of ammonia is drawn off by the stopcock, *d*, and the very weak liquor in the third condenser supplied instead, or it is recharged with a fresh quantity of water.

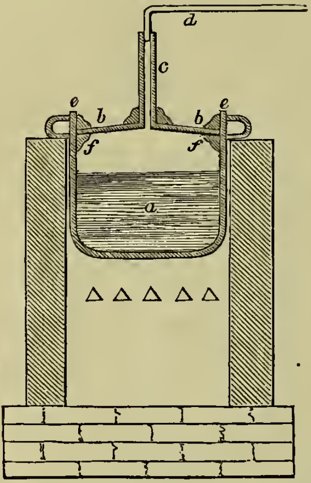
In this process it is very easy to produce, at each operation, an ammoniacal liquor of any standard strength, by furnishing each condenser with a glass gage pipe, graduated into equal parts, showing the bulk of liquid in the interior. Whatever be the quantity of water introduced, it expands in the ratio of six to ten, as before stated, on being completely saturated with the alkaline vapor, or in less proportion according as its gravity is reduced. At the first working, the measure of water employed is noted, and also the proportion of expansion, till it approaches that point which, by calculation, is found to correspond with the strength of the liquid required; this may be corroborated by drawing off portions repeatedly, and taking their density, and from this number the quantity of ammonia is ascertained by the aid of tables, which will be found further on. As soon as the exact point is gained, the gage is scratched at the level of the liquid, and this one test will serve for all future operations where the ammonia is to be made of the same strength; but it is necessary that the bulk of liquid should be always equal to that used in the first experiment.

When gas ceases to be evolved from the mixture in the retort, the fire is partly urged, and the stopper removed by means of a lever. If the stopper be so firmly fixed that it cannot be readily displaced, a cloth moistened with cold water should be carefully wrapped round it, without touching the neck of the retort; this refrigeration causes a contraction in its particles, and will enable the operator to remove it with facility. The residue—which is fused chloride of calcium, in the event of the chloride of ammonium being used—is then ladled out. Should sulphate of ammonia be operated upon, considerable quantities of water are employed, and the distillation should never be allowed to proceed to dryness, as in such a case the sulphate of lime formed would constitute a concrete on the bottom of the retort, which could not be removed without much labor and loss of time.

All the ammoniacal impurities which have collected in B during the first distillation are drawn off, and introduced into the retort in the second operation, to obtain the ammonia which they hold, and a small quantity of fresh water is substituted, to cover the lower end of the safety tube, as in the preceding operation. This apparatus, when once erected, will last for a long time.

A modification of the foregoing apparatus, represented in the annexed cut—Fig. 105—is sometimes employed.

Fig. 105.



a is an iron kettle, to which a metallic lid, *b b*, is adapted, resting upon blocks or ledges, *f f*, in the interior of the vessel. The lid is rendered air-tight by means of other bars of metal, *e e*, which are soldered fast on the outside over the interior ones. From the middle of the cover an iron pipe, *c*, rises, to the orifice of which another pipe, *d*, bent at right angles, is soldered, for the purpose of conducting the ammoniacal vapor to the condensers, which are similar to those already described. A much larger quantity of water must be used in this apparatus than in the preceding one; and as distillation advances, it is necessary to keep up the supply throughout the process, that the solder may not melt, a circumstance which would happen were this precaution overlooked.

Latterly, as the demand for ammonia and its salts became greater, its manufacture received an additional impetus, and several patents have been granted for its preparation; most of them, however, relate to the production of the salts of ammonia. Those patents which are considered to be improvements on the processes for obtaining ammonia directly for the manufacturer, as well as for other requisites, will be here noticed.

Mr. YOUNG, in 1841, took out a patent for preparing ammonia from guano; the method which he recommends is the annexed:—The retorts are filled vertically with two parts by weight of guano, and one part by weight of hydrate of lime, or other caustic alkali, and the whole is intimately mixed by the aid of an agitater placed in the retort. Having well mingled the materials, the retorts are moderately heated, and this heat is gradually increased to redness. The combined action of the heat and alkaline compounds disengages all the ammonia, whether it be in the form of salts or other complex bodies, such as urea or uric acid, and the gas thus liberated is received into a condenser filled with water. Other gases and fluids are evolved together with the ammoniacal vapor, the uncondensable portions of which pass through the condenser unaffected.

An ammoniacal solution is obtained by the destructive distillation of bituminous schist, for which a patent was granted in 1841 to COUNT DE HOMPESCH, who rendered it available for the manufacture of ammoniacal salts.

The method adopted under WATSON'S patent for procuring ammoniacal liquor from gas water—sealed in 1838—is as follows:—The gas water is run into a capacious retort, and a suitable quantity of slaked lime added—the amount being determined by the quality of the crude liquor; heat is then applied, and ammonia, tolerably pure, distils over, which, on being received in a vessel of cold water, forms an ammoniacal liquor. When considerable quantities of steam are observed to pass over with the vapor of ammonia, the strong alkaline solution already formed is removed, and this the patentee calls *the first portion;* that which is collected afterwards, by continuing the distillation, he names *the second portion;* the latter is weak or impure, and is returned to the boiler, with a second charge of lime and crude liquor, to undergo another distillation. The first portion from the previous operation is introduced into the retort, mixed with a small quantity of lime, if necessary, and as soon as the disengaged vapor carries steam with it, the strong liquor in the condenser is to be drawn off as before, and this he calls *the first portion of the second distillation.* The distillation is continued as long as it yields ammonia, and this secondary product is returned to the retort as before. The first portion of the second distillation is a concentrated liquid of sufficient purity for all ordinary purposes of scouring, cleaning, *et cetera*, but it may be still further improved by distilling a third time, in the same way as already directed, observing that the portion of solution which is made by the absorption of the ammoniacal gas is preserved, and the residue transferred again to the retort.

By far the most valuable of those methods which have been of late years submitted to the public, is that for which Mr. NEWTON took out a patent in 1841; it consists in the application of COFFEY'S still, described at page 76, but with a few modifications to adapt it to the distillation of the gas water. By its use the ammonia may be produced of any density up to its most concentrated state, and, consequently, of corresponding purity. Having made the reader already acquainted with the still in its application to the whisky trade, it will be unnecessary here to enter into lengthened details; those specific alterations which are peculiarly required by the operation, will, however, be pointed out. The number of diaphragms in the apparatus is increased or diminished according to the strength of the product which is to be produced, and the whole apparatus may be constructed of wood lined with sheet-lead, having the diaphragm plates in the interior of the analyzing column formed of perforated sheet-iron. Each of the sheets is supplied with several small valves, so weighted as to open upwards whenever the elastic vapor below the plate exerts more than a certain amount of pressure upon them, The ammoniacal crude liquid which enters at the top, passes downwards through each diaphragm successively, by means of a pipe rising about one inch above the level of the plate, the lower end of which is encased in a cup fixed upon the next diaphragm. The pipe must be sufficiently capacious to carry off all the liquid which enters at the top, and as the solution descends, it fills the small cup, and prevents the vapor from ascending at this part of the plate. Steam, as usual, is the medium which effects the elimination of the volatile body. According as the ammonia is to be procured, the supply of liquor, and the entrance of steam beneath, are regulated. When it is necessary that the ammonia should depart from the top of the rectifying column in the form of gas, the flow of liquid should be in proportion to the ascending steam, in order that the liquor in the top diaphragms may remain at little more than the normal temperature of the atmosphere, but become hotter as it falls towards the under reservoir, where it is retained for some hours at a boiling heat, to expel all the alkali. On the contrary, when it is necessary that the ammoniacal vapor should be in company with much steam, the stream of liquid entering is elevated to nearly its boiling point in the top diaphragms, by means of the larger volume of steam which is admitted from the boiler. Concentrated or dilute solutions of ammonia may in this way be obtained at once from salts, the acids of which are removed in the usual manner with lime or alkali; a product of considerable purity is also derived from the ammoniacal liquids formed by the distillation of bones or other animal matters; but, before submitting such liquids to the action of the heat, it is necessary to remove most of the impurities, and the combined acid, by the action of lime.

It is customary to have the diaphragms bent upwards, alternately, at opposite sides, so as to conduct the liquid from right to left, and conversely, till it reaches the bottom.

Carbonic acid gas, and other volatile compounds, which do not impair the use of ammonia in certain applications, may be eliminated from this still with the ammonia; but, in this case, as much steam should be generated in the liquor as will effectually prevent the solidification of the ammonia by the carbonic acid.

The specification of Laming's patent recommends that the solution of carbonate of ammonia, as obtained from bones, should be decomposed by means of chloride of calcium, instead of the mineral acids which are usually employed for that purpose; carbonate of lime is formed, and chloride of ammonium remains in solution. After filtering or siphoning this liquid, he boils it for an hour, by which treatment any gaseous impurities are expelled. As soon as the liquid has cooled, it is agitated, first with sufficient hydrated oxide of iron to precipitate any sulphide of hydrogen that may still remain, and next with lime enough to saturate the whole of the combined hydrochloric acid; it is then distilled. By this treatment a tolerably pure solution is produced. It is to be observed, that when ammonia is prepared on the large scale, according to the method first described, the dry salt and lime are often mixed in the retort, and as operations are going to commence, a quantity of water is added for the purpose of slaking the lime, and preventing the mass adhering to the bottom of the retort; by this means so much heat is generated that considerable portions of the ammonia are driven over to the receivers, and thus fuel is economised. To prevent the residue hardening when the distillation is carried to dryness, it is customary to add a few spadefuls of common salt to the mass.

Liquid ammonia is of different strengths, according to the more or less complete saturation of water with the gas. As the quality of the solution depends mainly upon the available ammonia it contains, it is the duty of the manufacturer, as well as of the purchaser, to be acquainted with its amount. Specific gravity tables have been constructed by various chemists, for the purpose of ascertaining the value of ammoniacal solutions. In the formation of these tables a great many experiments were performed with liquids of various densities, for the purpose of arriving at their content of ammonia, and the amount corresponding to the intermediate gravities calculated according to the known properties of this alkali.

Of these, the results of Dalton, Davy, and Ure are generally preferred. According to Davy, the appended table expresses the per centage in every hundred parts of liquid:—

Specific gravity of the liquid.	Per centage amount of ammonia.	Specific gravity of the liquid.	Per centage amount of ammonia.
0·8750	32·50	0·9435	14·53
·8875	29·25	·9476	13·46
·9000	26·00	·9513	12·40
·9054	25·37	·9545	11·56
·9166	22·07	·9573	10·85
·9255	19·54	·9597	10·17
·9326	17·52	·9619	9·60
·9385	15·88	·9692	9·50

Dalton attaches the boiling point and the volume of vapor in the mixture:—

Specific gravity.	Grains of ammonia in a hundred of the liquid.	Boiling points.	Volumes of gas in one volume of the solution.
0·850	35·3	26°	494
·860	32·6	38	456
·870	29·9	50	419
·880	27·3	62	382
·890	24·7	74	346
·900	22·2	86	311
·910	19·8	98	277
·920	17·4	110	244
·930	15·1	122	211
·940	12·8	134	180
·950	10·5	146	147
·960	8·3	158	116
·970	6·2	173	87
·980	4·1	187	57
·990	2·0	196	28

The following is the table of the strength of caustic ammonia compiled by **Ure**:—

Specific gravity.	Per cent. of ammonia.	Specific gravity.	Per cent. of ammonia.
0·8914	27·940	0·9363	15·900
·8937	27·633	·9410	14·575
·8967	27·038	·9455	13·250
·8983	26·751	·9510	11·925
9000	26·500	·9564	10·600
·9045	25·175	·9614	9·275
·9090	23·850	·9662	7·950
·9133	22·525	·9716	6·625
·9177	21·200	·9768	5·500
·9227	19·875	·9828	3·975
·9275	18·550	·9887	2·650
·9320	17·225	·9945	1·325

The gravity may be taken by an ammoniometer, or spirit hydrometer, or in a specific gravity bottle, which, at the ordinary temperature and pressure, holds a thousand grains of water.

Prepared by the usual method, ammonia is liable to be impregnated with chloride of ammonium and sulphate of ammonia, which are sublimed, and carried over mechanically. They may be detected by neutralizing a portion of the alkaline solution with pure nitric acid, and testing the liquid, divided into two portions—one with chloride of barium, for sulphuric acid; and the other with nitrate of silver, for hydrochloric acid. A white precipitate, or milkiness, will in either case prove the presence of the acid sought. Should any lime or chloride of calcium be carried over, which is rarely the case if ordinary precautions have been taken, it may be detected by evaporating the solution to dryness, and heating the residue to dull redness for a short time, to expel any traces of ammoniacal salts that may be present; the impurities will remain. If volatile organic substances be mixed with the compounds from which the ammonia is derived, they may be carried over with the vapor and condensed in the receiver; such matters are detected by the brownish or dark color they communicate to the solution. These impurities may, for the most part, be removed by filtering through animal charcoal. The charcoal absorbs some of the ammonia, and should be washed occasionally with water to abstract it; the washings may afterwards be distilled.

Ammonia has been a prolific field for theoretical and experimental researches, and there is, perhaps, no compound in chemistry more interesting, or which acts a more important part. On this account its true composition ought to be thoroughly examined, for the manufacturer would be quite abroad in his calculations of produce and decompositions, unless good data could be laid before him for his instruction and guidance. The reader must not suppose that the minute details given in this work are superfluous; every ascertained fact is a step in progress; the very numerous and important discoveries of the last few years afford room for valuable deductions, so suggestive of further advancement, that they must sooner or later be found serviceable to industrial enterprise.

Regarding ammonia, the view taken of it, previous to more modern theories, assumed that its composition in all cases was three equivalents of hydrogen combined with one of nitrogen—NH_3; this being substantiated by the analysis of the dry gas, as indicated by the formula at page 178. When this compound united with water, or any of the hydracids, such as hydrochloric, hydrobromic, or hydriodic acid, the combination was presumed to have taken place without any change being effected in either body, and the formula, or symbolical representation of such compounds, was $NH_3\,HR$; R being any negative radical, such as oxygen, chlorine, bromine, or iodine. On the other hand, when NH_3 united with oxacids, the same isolation of the ammonia was preserved, and the formula of the salt, say the sulphate, which may be instanced as a type, ran thus:—NH_3, HO, SO_3. Now, as there exists an undoubted analogy between all the salts which ammonia forms, both with hydracids and the so-called oxacids, and the similar compounds which such acids form with the other alkalies, and some of the metals and metallic oxides, **Berzelius**, to establish a corresponding one in their symbolical representation, assumed that ammonia was the oxide of a hypothetical metal, *ammonium*, the symbol of which was NH_4, analogous to the other metals. The fact that the compound, ammonia, in the former view, required in every instance an equivalent of hydrogen in the acid, or water, to form a corresponding salt or hydrate, seemed to justify the hypothesis of the great Swedish chemist so far that his view has been almost universally adopted; for—

$$\underbrace{NH_3, HO}_{\text{Ammonia of the former view.}} = \underbrace{NH_4O}_{\text{Ammonia of the Berzelian view.}}$$

And in like manner—

$$\underbrace{NH_3, HCl}_{\text{Hydrochlorate of ammonia by the old view.}} = \underbrace{NH_4Cl}_{\text{Chloride of ammonium, by the Berzelian theory.}}$$

In the same manner the composition of the salts formed with oxygen acids, such as the sulphate, was represented in the old nomenclature as NH_3, HO, SO_3, while in the Berzelian it is NH_4O, SO_3. In this way was introduced a happy conformity in the formulæ, corresponding to that analogy in properties and appearance existing between the salts of ammonia and those of other metals similarly constituted.

But if it be assumed with **Berzelius**, that the metal ammonium exists, and that, as previously explained, the hydrogen of the acid associated with the NH_3 of the old view, is necessarily abstracted by the NH_3 to constitute the supposed metal—then, to support this assumption, another must be admitted which is highly improbable, namely, that the affinity which the radicals of the hydracids manifest for hydrogen is less powerful than that of the gaseous compound NH_3. And, again, if it be supposed that the compound of hydrogen and nitrogen, in the proportion of four of the former to one of the latter, is a metal, on account of the relations which seem to bind it to the other metals, and their combination with other compounds—by the same argument it must be admitted that PH_4 is also a metal, for the terhydride of phosphorus PH_3 reacts exactly like NH_3 towards hydracids; thus, when influenced by hydrochloric or any such acid, instead of PH_3, HCl, it is by the Berzelian demonstration PH_4Cl, constituting this compound, PH_4, a metal analogous to ammonium, NH_4, or to potassium, K, or any such metal.

KANE, in his investigation of the ammoniacal compounds, regards the dry gas, and in fact all the ammoniacal bodies, as springing from a radical, *amidogen*, whose formula is NH_2, having the closest analogy to oxygen and chlorine. According to this view, dry ammoniacal gas is represented as an amide of hydrogen—

$$\underbrace{NH_3}_{\text{Ammoniacal gas.}} = \underbrace{NH_2 + H}_{\text{Amide of hydrogen.}} \text{ or } H + NH_2$$

Ammonia, according to the chemist above-mentioned, possesses the property of a feeble base, and is capable of uniting with dry hydracids, as chloride of hydrogen—hydrochloric acid—forming chloramide of hydrogen, HNH_2, HCl—chloride of ammonium. It also enters into direct combination with dry oxacids, but it does not then form the proper ammoniacal salts, which all contain an *essential* atom of water. NH_4 of the Berzelian nomenclature is described by KANE as a subamide of hydrogen, $NH_2 + 2H$, or H_2NH_2; and this compound with oxygen he regards as an oxamide of hydrogen, H_2NH_2O, or HNH_2, HO.

Another peculiarity of the bodies which amide of hydrogen forms with acids, is their isomorphism with those of the magnesian family of compounds, consequently requiring two equivalents of base; thus, NH_4O, SO_3, is regarded as HNH_2, HO, SO_3, and here the HNH_2, HO, is isomorphous with potassa and soda.

Each of these theories asserts a claim to probability, and might be regarded as a true exponent of the behavior of the compounds in question; but none of them will obviate all objections. The generality of the chemists concur in ascribing the preference to the Berzelian view: first, because it is more simple, and as regards the combining link which it forms in the series of analogous compounds of non-metallic bodies, the formulæ of the ammonia series of salts are more in harmony on this hypothesis than on any other. At the same time it must be borne in mind, that although the chemical relations of the ammonia salts confirm the ammonium theory, still, neither ammonium nor its oxide is capable of existing uncombined.

Ammonia unites with all acids, forming salts. Those manufactured to any extent are, the chloride, the sesquicarbonate, the sulphate, and the acetate.

CHLORIDE OF AMMONIUM, or SAL-AMMONIAC.—The manufacture of chloride of ammonium was first practised by the Arabians, although it has been attributed to the Egyptians. The term *sal-ammoniacus*, which is very ancient, has been applied by modern historical writers to the substance which is now understood by that name; but whether the ancients, at the period in which this term was used, applied it to our chloride of ammonium, is a doubtful point. PLINY and his cotemporaries were unacquainted with sublimation in any shape; and it is a fact, that even the process of lixiviating earths, or crystallizing saline substances from their solutions, was so ill understood, that the native compounds, however impure, were employed in the manufacture of inks, colors, *et cetera*. From the many evidences and arguments adduced by BECKMANN, it is almost certain that the sal-ammoniacus of the ancients was no other than common *rock salt.* Indeed, the uses to which it is stated the sal-ammoniacus was then applied, leaves no doubt that the chloride of ammonium was not meant. The Arabian writers are the first who transmit accounts of the true sal-ammoniacus. GEBER furnishes a prescription for its purification by sublimation, and another for its preparation; still BECKMANN throws a doubt upon the authenticity of these statements, as to their being GEBER'S, on account of the various additions which were introduced into his works by more modern writers.

Sal-ammoniacus was an article of trade about the year 1410; but the purposes to which it was applied, or the mode of its preparation in Egypt at that period, have not been recorded. In the sixteenth century many of its properties were known, particularly its behavior with nitric acid by which aqua-regia is formed.

The younger GEOFFROY was the first who showed that it consisted of hydrochloric acid and volatile alkali, and that it could therefore be produced in Europe by sublimation. An account of the sal-ammoniac—chloride of ammonium—manufactories at Damayer, in the Delta, was given, in 1720, by a Jesuit named SICARD. It is uncertain at what period the manufacture became general in Europe. Large manufactories of this article were instituted in Scotland from the year 1750 to 1756. Chloride of ammonium was discovered in the mineral products of volcanic districts, so early as the fifteenth century. It is generally met with, sublimed among other volatile bodies, in the fissures of lava, particularly at Vesuvius, Etna, in the Island of Volcano, and at the Solfatara, near Naples. Small quantities of it have been found in the vicinity of ignited coal-fields, as at St. Etienne in France, in Scotland, and at Newcastle. A variety, possessing a greyish-white color, of a conchoidal fracture, has been mentioned as occurring in Bucharia. The native salt is generally massive, has a fibrous texture, is sometimes plumous, in crusts, and in minute octahedral crystals; its color, when pure, is white, grey, or yellow; transparent or opaque; externally dull or glistening, and internally shining or vitreous. The salt has a pungent and saline taste, is readily soluble in water, but does not attract moisture on exposure to the air; it completely volatilizes in white fumes at a high temperature, and emits, when triturated with lime, a strong ammoniacal odor.

Two samples, from Vesuvius and Bucharia, yielded to KLAPROTH the following results:—

	Vesuvius.	Bucharia.
Chloride of ammonium, ...	99·5	97·5
Sulphate of ammonia, ...	0·5	2·5
	100·0	100·0

Chloride of ammonium is prepared by the chemist simply by neutralizing pure ammonia with hydrochloric acid, or by transmitting a stream of the gas into a solution of this acid till saturated, and then evaporating and crystallizing the salt. The properties of the chloride, in a chemical point of view, are not very characteristic, though in a manufacturing light the compound is highly important; these, however, will be mentioned after the reader becomes familiar with the chief methods followed in its preparation on a large scale. In Egypt, which undoubtedly was the great seat for its manufacture from the thirteenth to the middle of the seventeenth century, and whence all the European markets were supplied, the following is the process by which they obtain it.

The great source is the urine and dung of the camel, which, as Ure relates, are dried, by plastering them upon the walls, and burned instead of other fuel, which is very scarce in that country. A fire of this material evolves a thick smoke charged with chloride of ammonium, part of which is condensed in the soot; and on this account the latter is carefully collected throughout the country, particularly in the Delta district, and brought to the sal-ammoniac factories, for the purpose of distillation. The first accurate account of the manner of manufacturing the salt in Egypt, was transmitted thence to Europe by Lemere, French Consul at Cairo, in 1770. The soot was put into large round glass bottles, which were externally coated with loam, in order that they might bear the heat better; these bottles were ranged in a long ridge or terrace, in such a way that only the necks were exposed to the air, while the flue from the furnace circulated freely round each of the bottles. These bottles, or globes, were generally a foot and a half in diameter, and the necks about two inches long. Forty pounds of soot formed the charge, filling each of them to within four inches of the neck; and from this weight of material about six pounds of the salt were obtained. A fire, made of dry camel's dung, heated the range of bottles; on the second day, when the bottles became heated, the salt commenced subliming, and much care then became necessary on the part of the attendant to keep their necks free for the passage of the uncondensed vapors. Towards the conclusion of the operation, the fire was urged to bring the globes to incipient redness, that the last portions of the salt might be disengaged. At the end of the third day the fire was extinguished, and as soon as the globes cooled they were taken out, broken, and the cake of salt abstracted, which in this form was exported to Europe. On breaking the bottles, a nucleus of the salt was found surrounded by a fixed pulverulent substance, which was taken out and mixed with fresh portions of the soot in the succeeding operation. Evidently, considerable quantities of the salt were lost by this mode of preparation.

Geoffroy relates that chloride of ammonium was imported from India, where it was manufactured in much larger quantities than in Egypt. It assumed in the subliming vessel the form of a sugar loaf, and weighed about fifteen pounds. These loaves were composed of three distinct layers; the upper of each was impure, and was generally cut off. Egyptian and Indian sal-ammoniac was a dull, spongy, and greyish mass, considerably inferior to the compound now made; nevertheless, on account of its scarcity, it commanded a price more than six times that of the *pure* article at the present time.

Before the introduction of gas-lighting, the chloride of ammonium made in Europe was obtained from offal or the refuse cake of oil presses, either by allowing it to undergo the putrefactive fermentation, or submitting it at once to destructive distillation; the latter course was adopted in Germany. In this country, soot deposited from pit coal was once employed to yield the salt. The distillation of pit coal affords considerable quantities. The first factory of any extent which was formed in France for the preparation of ammoniacal products from this substance, was under the superintendence of Beaumé; it failed after twenty-seven years' standing, leaving the shareholders sufferers to the amount of four hundred thousand francs—another, among many instances on record, of a purely theoretical chemist not being always the fittest person to conduct a manufacturing operation.

At present the salt is extensively made from bones, which are distilled in iron retorts, for the preparation of charcoal for depurating purposes. The accompanying drawings—Figs. 106, 107, and 108—represent the furnace used by the French for distilling bones, and obtaining the ammoniacal compounds and the oil from them.

Fig. 106 is a longitudinal vertical section of the retort, A A, for holding the bones, showing its position in the dome of brick which encloses the fire, B. The flue, after passing round the retort, is shown to advance to the front of the furnace, as at D, before it returns by the arch, E, and enters the chimney, J, at the back. The pipe, G, emerging from the far end of the retort, enters the cylinder, H—Fig. 108—into which it conducts all the eliminated products of the distillation.

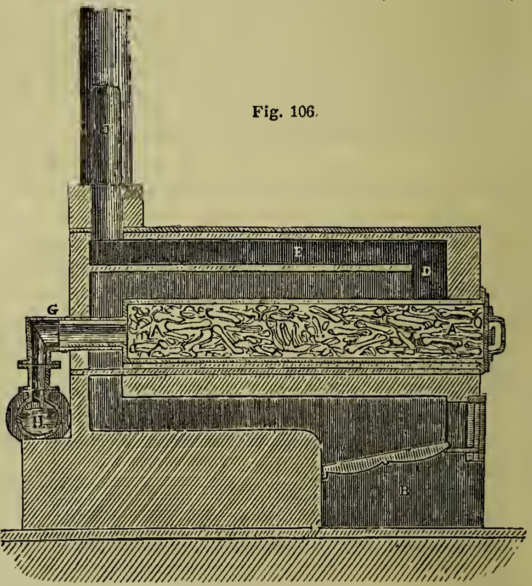


Fig. 106.

Fig. 107 is a vertical section of the series of retorts and furnaces, made at right angles with Fig. 102, and parallel to the front elevation. A A A are the retorts, and B B B the furnaces, placed immediately under, though not in contact with them. This figure shows more clearly the circuitous passage of the flame and heated strata of vapor from the fires, B, surrounding the retorts laterally at C C, and horizontally at D D, above, as well as at the fireplace below. When the heated air reaches the front of the chambers, D, it returns, as seen in Fig. 106, by the space, E, to the chimney, J. On the right is shown the safety-valve, K, by which air is admitted into the apparatus when the distillation of a charge has been finished; and at the opposite side is seen a portion of the pipe which conducts the uncondensed vapors to the refrigerator.

Fig. 107.

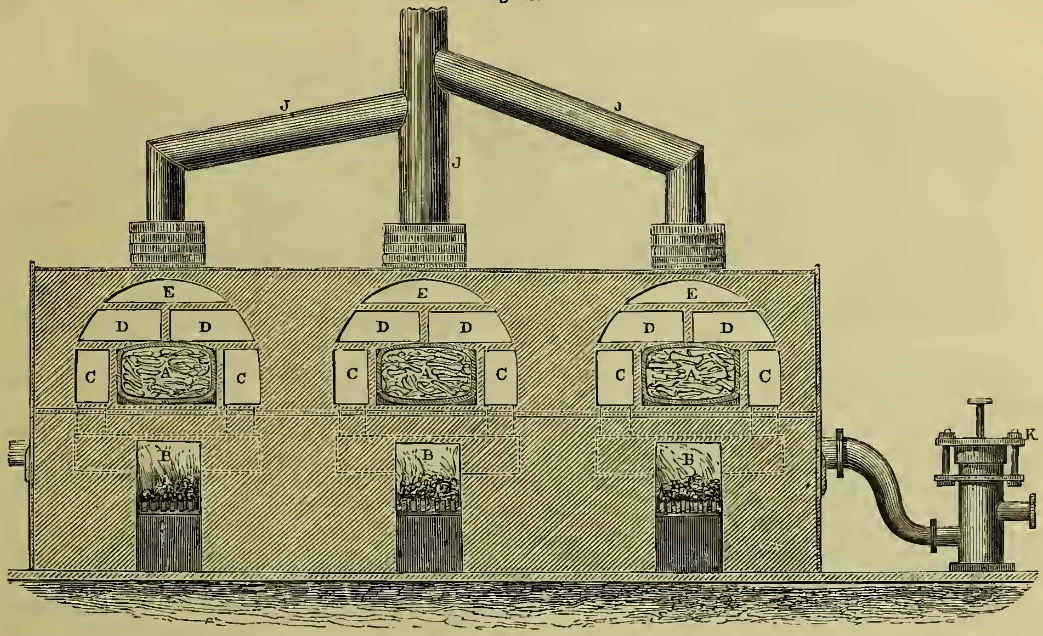


Fig. 108 exhibits a horizontal section of the flues surrounding the retorts, with a view of the condensing pipes from above. In this figure the flues are seen to rise from the canals, C C, to the chambers, D D, at the back, through *f f*, and from D they pass off similarly to E, at the front, as in Fig. 106. The condensing pipes, H and I I, are seen vertically; the latter are rather inclined, and enclose the entrance pipe, while the surrounding space is kept replenished with cold water, which enters at the lower, and is discharged at the upper pipe, as it becomes warm. This arrangement is shown in the section, K. From the end of the last refrigerator, the condensed products are discharged into a suitable receiver, where the oil collects at the top in a layer, and is skimmed off, leaving the ammoniacal liquor, to which the appropriate acid, whether hydrochloric or sulphuric, is added in proper proportion, till the solution is neutralized; the liquid is then pumped, or otherwise transferred, to the evaporating pans to be concentrated.

Fig. 108.

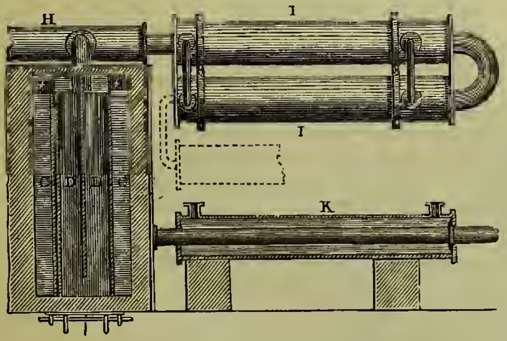
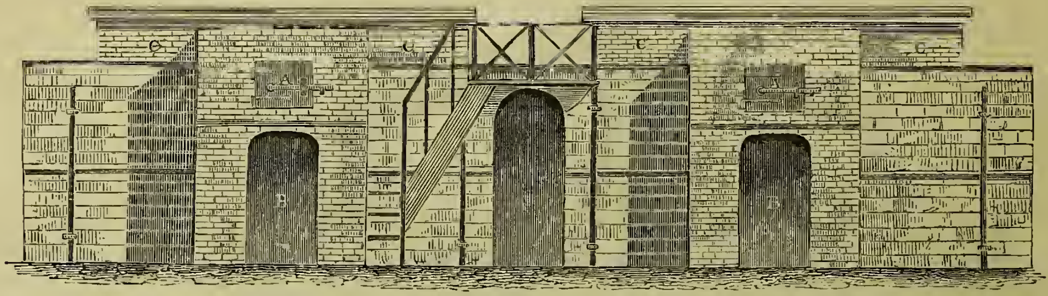


Fig. 109 represents a range of such evaporating pans as are used in France. A A are the fires, B B the ash-pits, and C C C C the evaporating pans, which are about nine feet square, and eighteen inches in depth, and are formed of sheet-lead; their front rests upon a dome of firebrick, and the remainder is supported by cast-iron plates, resting upon supports of brickwork, which serve to disseminate the heat of the furnace under the bottom of the pan.

In Fig. 110, A shows the firebars of the furnace, and C the course of the flame, interrupted repeatedly by the upright brick walls, serving the double purpose of equalizing the heat under the pan, and of supporting the iron plates on which it is laid.

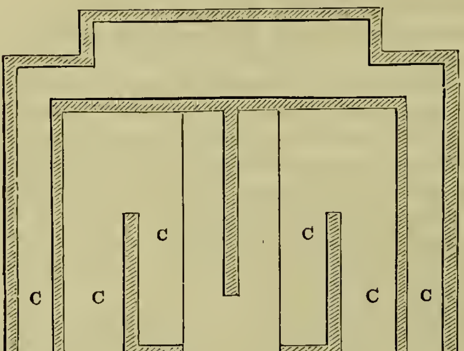
When impurities pass off in large quantities from the distillation of the bones, and are condensed in the liquid, they are almost entirely separated in the tank on the addition of the acid; and, before evaporation, it is found necessary to remove them completely, which is most conveniently done by a process of filtration. The filters consist of a long wooden box lined with sheet-lead, and having an outlet pipe at its lowest end, for the purpose of drawing off the liquid into the receiver. A frame, corresponding to the shape of the vessel, is adjusted by means of wedges, perfectly horizontal, and within an inch of its bottom. Round bars of wood are fixed lengthways in this frame, and upon it a canvas or stout linen cloth is drawn tightly, being secured at the sides and ends of the frame by means of tacks. On passing the liquid through this cloth, most of the solid impurities are withheld; and in order that there may be as little of these as possible retained in the liquid, it is returned by means of a pump from the tank two or three times, to undergo fresh filtrations. A common receiver, placed below the others, may be made to communicate with any of the filters by means of intermediate stopcocks.

Fig. 109.



When the liquid is sufficiently clear, it is pumped up into the evaporating pans just described, and concentrated. As soon as the liquid acquires a certain gravity, it is drawn off to the crystallizing pans. These are wooden boxes, lined with sheet-lead, and are of various dimensions, from six to ten feet in length, three to six feet in breadth, and one and a half to three in depth. When the mass of salt is crystallized, the crystallizers can be inclined towards either side, in order to drain off all the mother liquor, which is received in an appropriate cistern, and is afterwards pumped into the evaporating pans, to be concentrated with another portion of the ammoniacal liquor; the pump employed is made of lead, hardened with antimony and tin.

Fig. 110.



When the crystallized chloride of ammonium is well drained, it is submitted to the subliming process. The arrangement used for this purpose is represented in the annexed woodcuts—Figs. 111 and 112.

The sublimers are earthen or stoneware pots, placed in two ranks, upon the arch of the flue, passing from the fire, A, which heats them. The longitudinal section of the furnace—Fig. 111—shows one row of these pots. Under the pots, represented in the engraving by D, circular openings from the main flue are made in the arch of brickwork, by which the heated vapor and flame are made to circulate around them, and thus they become hot enough to sublime the salt. The bottles, or pots, are encased in the furnace to their necks, as seen in the front view and transverse section in Fig. 112; and a plate of iron, with indentations corresponding to the size of the bottles, runs along between the two lines, as shown at B B. The space between this plate and the dome on which the bottles rest, is left for the free circulation of the flame and heated air of the furnace, which effects the sublimation. To economize fuel an evaporating pan is often appended to the subliming furnace; and the heated air from the chamber of sublimation, as it passes to the chimney, is made to run along a number of square openings, over which the evaporating pan is supported by cast-iron plates, and at the end of this pan they unite into one flue, just before entering the chimney.

The salt is generally dried in this manner previous to being sublimed.

The pots are of variable dimensions, but those most frequently employed are about eighteen inches in height in the body, and the caps about ten or twelve inches, with a breadth of sixteen inches at the widest part. The annexed numbers show the produce of a large French manufactory of ammonia and its salts, from the distillation of bones and other matters. The materials were—

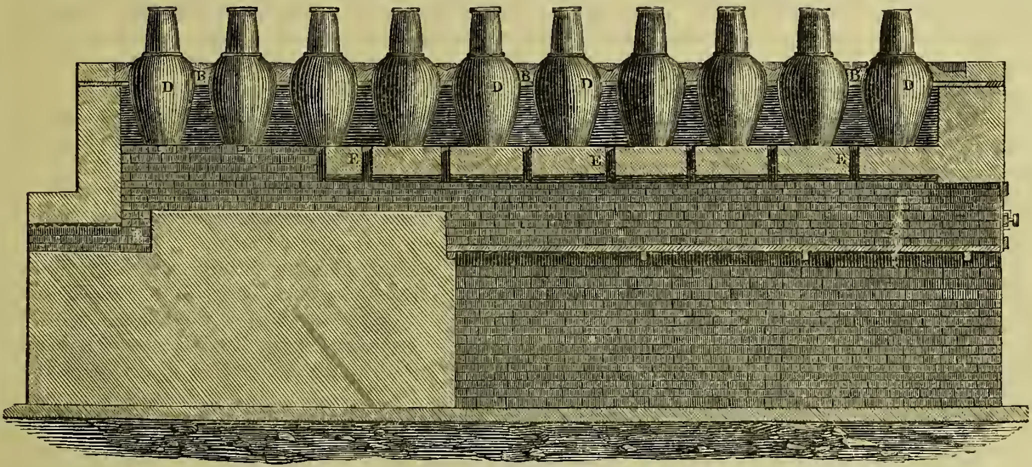
46,754	tons	of bones of various kinds,
30	"	silk waste and old leather,
11½	"	sulphuric acid,
80	"	chloride of sodium, and
2¾	"	sulphate of lime;

and the produce—

2,400	tons	of animal charcoal,
44	"	chloride of ammonium.
100	"	sulphate of soda,
4	"	liquor ammonia, and
25	"	sulphate of ammonia.

In this manufactory, the sulphate of ammonia is obtained by treating the ammoniacal liquor—which contains chiefly carbonate of ammonia—with sulphate of lime, when double decomposition takes place, carbonate of lime and sulphate of ammonia being formed. The latter remains in solution, and may be obtained by filtration from the lime precipitate, and subsequent evaporation of the solution in the manner indicated by the preceding sketches of the apparatus employed.

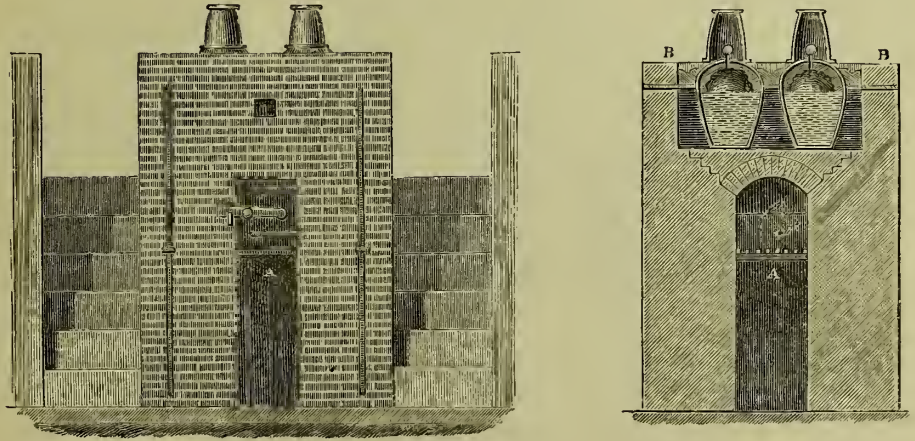
Fig. 111.



The chloride is prepared either by adding the hydrochloric acid at once to the crude liquor, and evaporating it, or by converting the ammonia into the sulphate, and decomposing this salt by chloride of sodium, which causes the formation of sulphate of soda and chloride of ammonium; the latter is separated by sublimation. Occasionally, the chloride of manganesium, from the refuse liquor of chlorine stills, is used to decompose the crude carbonate of the alkali; the carbonate of manganese precipitates, and is separated by filtration, and the solution of the ammonia salt is treated as in the other instances.—*Pharmaceutical Journal.*

Ure states, that when offals are used to procure ammonia by their destructive distillation, they should not be heated beyond the ordinary temperature required to disengage their ammoniacal compounds, in order that the charcoal which such matters yield may be available in the manufacture of prussian blue. According to this chemist, the density of the liquor from the distillation of the bones and other substances, when mixed, is 1·060; and when the chloride of ammonium is prepared by means of sulphate of lime and common salt, the following is the method pursued:—

Fig. 112.



The crude carbonate of ammonia is decomposed by passing it through a bed of sulphate of lime, three or four inches thick, which is spread out upon filters. The liquor may be poured upon the gypsum by means of a pump, but it should never stand higher than from one to two inches above the surface of the coarsely ground salt, and to prevent the dissipation of any of the volatile alkali, the vessel should be closely covered over with boards. When the liquor has passed through the first filter, it must be pumped upon the second; or the filters being in a terrace form, the liquor from the first may flow down upon the second, thence upon a third, and so on in succession. The last filter ought to be composed of nearly fresh gypsum, so as to insure the thorough conversion of the carbonate into sulphate. The resulting layers of carbonate of lime should be washed with a little water, in order to extract the sulphate of ammonia interposed among their particles. The ammoniacal liquor thus obtained must be completely saturated, by adding the requisite quantity of sulphuric acid; even a slight excess of the acid can do no harm. It is then to be evaporated, and the oil, which is generally carried off in the ammoniacal liquor in combination with the alkali, and is set free by the slight excess of acid, must be skimmed off in the course of the concentration. When the liquid sulphate has acquired the density of 1·160, chloride of sodium should be added with constant stirring, until the whole quantity required for the double decomposition is introduced into the boiler. The liquid portion must now be drawn off by a siphon into a somewhat deep reservoir, where the impurities are allowed to subside; it is then evaporated by boiling, till the sulphate of soda falls down in granular crystals—as the result of the mutual action of the sulphate of ammonia and chloride of ammonium, thus:—

$$\underbrace{NH_4OSO_3}_{\text{Sulphate of ammonia.}} + \underbrace{NaCl}_{\text{Chloride of sodium.}} = \underbrace{NH_4Cl}_{\text{Chloride of ammonium.}} + \underbrace{NaOSO_3}_{\text{Sulphate of soda.}},$$

while the chloride of ammonium, being more soluble, remains in the liquid. During the precipitation of the crystallized sulphate of soda, the whole of the liquid must be agitated by wooden paddles, or spatulas, the precipitate being in the intervals removed to the colder part of the pan; thence it is taken by means of copper rakes and shovels, and thrown upon the draining copper placed near the edges of the pan. The drained sulphate of soda must be afterwards washed with a little cold water, to extract all the adhering chloride of ammonium. The liquor thus freed from the greater part of the sulphate, when sufficiently concentrated, is to be drawn off by a leaden siphon into the crystallizers, where, at the end of twenty or thirty hours, it affords an abundant crop of crystals of chloride of ammonium. The mother water may then be run off from the crystallizers, which should be placed in an oblique position to drain the salt; when this is done, the crystals must be washed, first with a weak solution of chloride of ammonium, and next with a small quantity of water. The mass of crystals is then desiccated in a furnace, where all the moisture is removed, after which it is put into the earthen subliming bottles by means of a funnel, and rammed down tightly; the heads are then placed securely on, and heat cautiously applied, so as to effect the sublimation of the pure salt from the bottom to the upper part of the bottle, and the vent hole, as shown in the section of the bottles in the foregoing Fig. 112, must be cleared from time to time, by means of a long steel skewer, to prevent the risk of choking, or consequent bursting; in spite of these precautions it happens, however, that several of the bottles crack in almost every operation.—*Ure.*

The preceding method of sublimation is never followed in the manufactories of ammoniacal salts in this kingdom, though a process somewhat analogous is pursued in Glasgow, where the salt is expelled from cast-iron pots, lined with fireproof tiles; the vapors are received and condensed in a hollow globular head of green glass, with which each of the iron pots is capped. The chloride of ammonium thus formed is sold in hollow spherical masses, corresponding in shape to the head of the vessel, being previously freed from any adhering impurities by mechanical means. The residuary matter left in the pots, which still retains some of the salt, is lixiviated, and the liquor worked up in another operation.

Ammoniacal salts are now more extensively produced from the crude liquor of gas-works than from any other source; this has dispensed with the disagreeable necessity of collecting and storing putrid urine for the purpose—a practice formerly extensively followed.

In a large Glasgow factory, where upwards of seventy thousand gallons of gas liquor are consumed weekly, it undergoes the following treatment:—The liquor is first rectified by distillation from a waggon-shaped wrought-iron boiler, into a square cistern of iron lined with lead. Forty-five hundred pounds of sulphuric acid, of specific gravity 1·625, are then added slowly to the somewhat concentrated distilled ammoniacal water. The produce is about twenty-four hundred gallons of solution of sulphate of ammonia, slightly acidulated, of specific gravity 1·150, being of such strength as to deposit a few crystals upon the sides of the leaden-lined iron tank, in which the saline combination is made. This liquid is decomposed with common salt to obtain the chloride.

The following routine is practised at the factory of Messrs. Kurtz, Cropper, and Co., in Liverpool, who kindly laid the whole of the several processes open to the Editor's inspection. The gas-works supplying the crude liquor are situated on each side of the factory, at the distance of three quarters of a mile; a communication is opened by means of a canal, on the banks of which are the two establishments. Flats, constructed of sheet-iron, and divided into compartments of known capacity, convey the ammoniacal liquor to the factory. As soon as the flat comes alongside, the gas liquor is drawn off by a hose, eight or ten yards long, to a receiver placed within the walls of the premises; thence it flows through a conduit pipe to large subterranean cisterns, capable of holding a hundred thousand gallons or more, which are situated nearly in the middle of the factory, and adjacent to large tuns, each capable of holding fourteen to eighteen thousand gallons. Fig. 113 shows the front of these tuns, and the general apparatus appended to them.

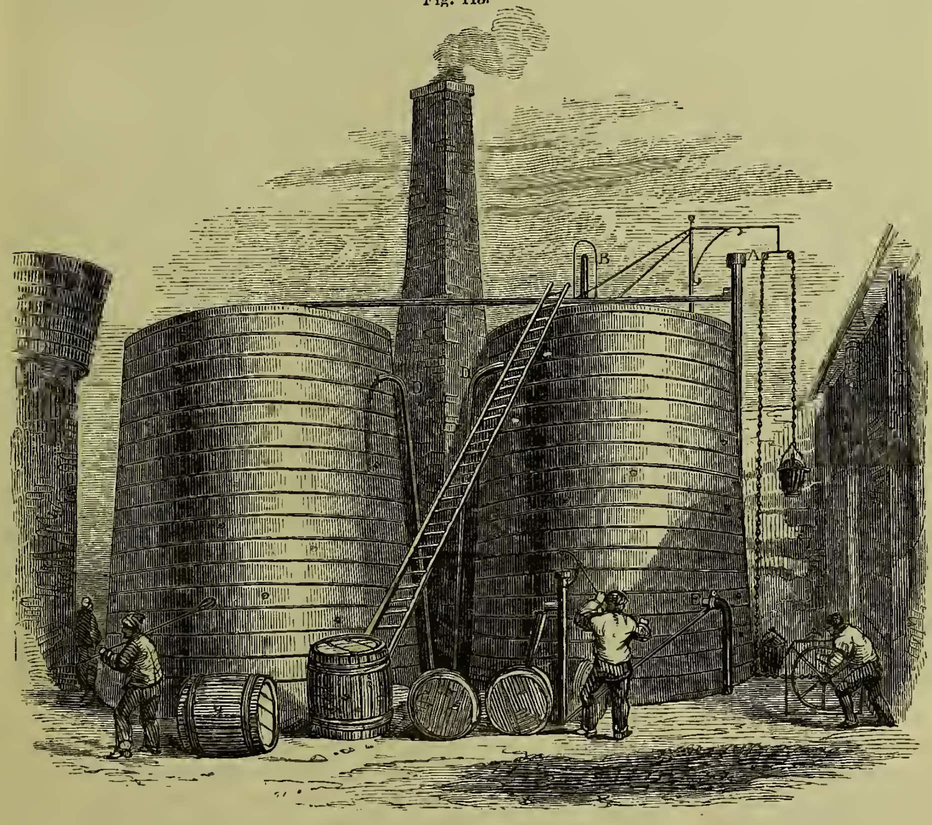
By means of a pump, A, connected with the reservoirs, the crude liquor is raised into the tuns; and after a considerable quantity has been pumped, strong hydrochloric acid, in the proportion of one and a half or two pounds to the gallon of the crude liquor, is introduced by the aid of a pulley, or crane, and gutta percha carboys, as shown in the engraving. Metallic pumps cannot be used, on account of the corrosive action of the acid, and even pumps made of gutta percha do not answer.

When the proper quantity of acid has been added, both liquors are intimately mixed by an agitater placed within the tuns, and worked by the same machinery as the pump in connection with the subterranean reservoir; this machinery, however, is not seen in the figure. Disagreeable vapors, in large quantity, consisting of sulphide of hydrogen and other injurious gases, are disengaged during the saturation of the liquid; these are not permitted to escape into the atmosphere, till they first traverse the fire belonging to the steam-engine, being conducted thither by the pipes, D D.

The liquor in the tun should have a faint but distinct acid reaction. The hydrochloric acid, besides uniting with the ammonia, causes the tar and other bodies, held mechanically and in solution, to separate and subside to the bottom of the tun in the course of three or four days, leaving the supernatant liquor much purer, but still deeply colored.

It is then drawn off at several outlets, shown by the dots in the sides of the tuns, but which are kept plugged during the previous part of the operation, and conducted by small sluices or troughs, appended to them when required, to the store vats and the several concentrating pans, all of which are constructed of cast-iron plates riveted together. The deposits of tar and other matters are drawn off at the lower openings, or by the tap in the pipe, E, when they have accumulated to that elevation, though this rarely happens, to a well or reservoir adjoining, whence they are pumped into barrels, to be carried to another department of the factory, as shown in the sketch. When there is a superabundance of crude ammonia liquor, it is conducted by the pipe, E, to the sulphate of ammonia works in this establishment.

Fig. 113.

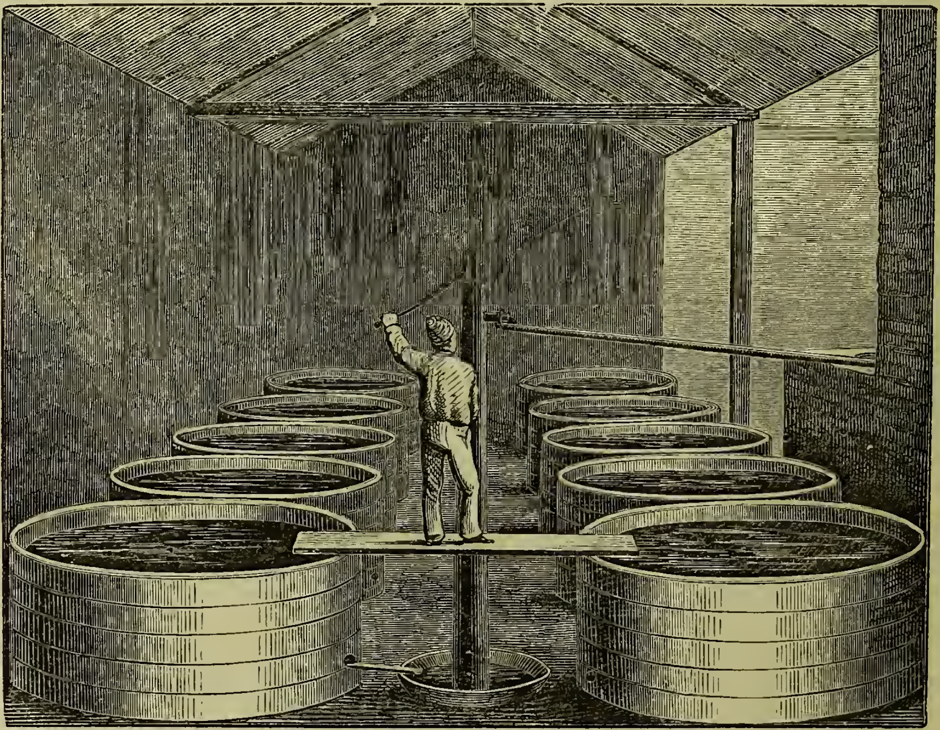


The evaporators are square, rectangular, or circular cast-iron vats, capable of holding from eight to fifteen hundred gallons; some of them are partly incased in brickwork. Heat is applied usually by a fire, the flue of which takes a sinuous course beneath the lining of brickwork on which the pan rests. During the concentration, considerable quantities of petroleum and other impurities, not deposited in the tun, separate, and are immediately removed by skimming. The liquor, which marked only 5° Twaddle previous to being submitted to the action of heat in the pans, is of 50° Twaddle, or 1·25 specific gravity, when transferred to the crystallizers. As the solution is slightly acid when drawn over from the mixing tun, this acidity becomes more distinct as the excess of water is dissipated, and might be productive of inconvenience if it were not neutralized from time to time by the addition of quicklime or chalk in small quantities; but a more economical way would be to saturate it with ammoniacal liquor. The neutralizing is advantageous likewise in precipitating any sesquioxide of iron which might prove deleterious in the subsequent operations. The liquid being brought to the gravity 1·25, as above noted, is run off to the crystallizers, which are for the most part circular tubs, from seven to eight feet in diameter and two to three in depth; they are partly imbedded in, or rest upon, the ground.

Fig. 114 is a view of a range of these vessels; they are so placed that the concentrated solution of the chloride of ammonium can be drawn into them from the boilers.

According to the state of the weather, the salt crystallizes out in four or six days. In crystallizing the chloride of ammonium, it is not desirable to have large and well-defined crystals, especially when the salt is afterwards submitted to sublimation; the process becomes much more difficult with such crystals than with the more divided salt, on account of the cohesiveness of the former, which has to be overcome by the comparatively small surface exposed to the heat. On the contrary, when small crystals are submitted to the heat, the cohesion offers scarcely any resistance, and a greater surface is exposed, so that, in this instance, the sublimation proceeds rapidly. Hence, when the solution of the salt is set to solidify, the crystals which form on the top, as well as those on the sides and bottom of the vessels, are broken by agitating the liquor every six or eight hours, according to its state of concentration. Eight or ten days are allowed for the salt to crystallize, after which the mother liquor is removed through an opening at the bottom to a well sunk in the ground, whence it is again pumped into the concentrating pans as shown.

Fig. 114.



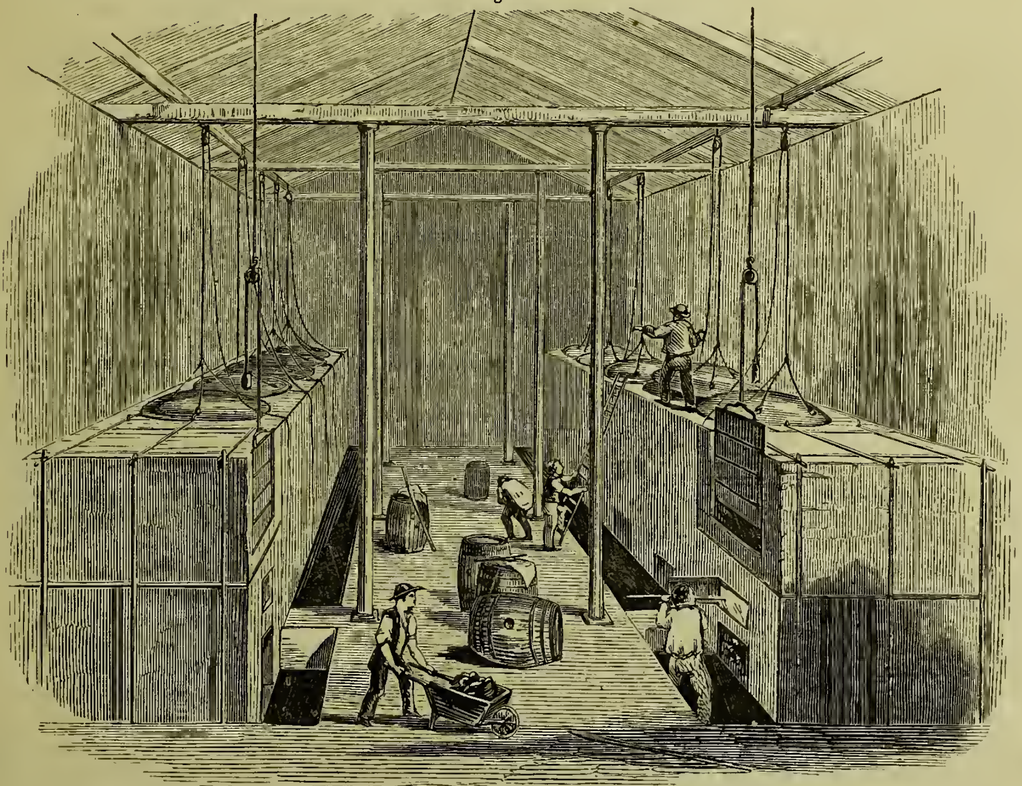
Chloride of ammonium, as obtained by the first crystallization, is a blackish salt, interspersed with moderately large cubical crystals. The blackness arises from tarry, oleaginous, and other impurities, mechanically held in the liquor, which fall down, more or less, with the crystals; the chloride also contains mechanical water, some sulphates and hyposulphites, all of which tend to deteriorate the quality of the article, if the mass were submitted to sublimation in their presence. To get rid of these impurities as much as possible, the well-drained crystals are introduced into the bed of a drying furnace, covered with a cast-iron plate, the whole surmounted with a dome of brickwork, and erected near the sublimers. This drying bed is heated by a fire placed under it, the flue of which is brought several times into such a position that the plate is within its influence. The charge introduced into this chamber, which is between six and eight feet in length and about four feet in breadth, is sufficient to cover the entire plate to the depth of four inches. The heat should never be raised to a high degree, lest some of the salt be volatilized. When all the water and free acids are removed, and the tarry impurities for the most part decomposed, the greyish-white mass is drawn out and supplied to the sublimers, where the salt is eliminated from the foreign impurities.

The sublimers are circular spaces, constructed in a mound of brickwork, walled interiorly with firebrick, and lined with cast-iron plates, round the sides of which the flue from the fire underneath coils, after it passes from the bottom. These subliming vessels are capped by a cast-iron cover, somewhat of the shape of a flat-bottomed watch-glass. They are from three to nine feet in diameter, and their concavities about two; they weigh from ten to thirty hundred-weight. Three rings, at equal distances, allow of their being lifted off by means of a pulley and chains which can be attached to these rings. When in active operation, a pressure of from three to four pounds per square inch bears against them, which requires their being firmly fixed to the flat rim of the body of the subliming vessel. In the centre of some of these is a small hole, which is closed by an iron spindle; this is removed from time to time, to allow any elastic uncondensable products to escape.

The annexed woodcut—Fig. 115—is a view of these sublimers and drying furnaces. They are heated by the fires, which are briskly kept up till the sublimers and their surroundings attain a sufficient degree of heat; they are then slackened, and maintained at a mean temperature.

Much of the success of the sublimation depends upon the regulation of the heat; too high a temperature will not answer, for then large quantities of empyreumatic bodies would be disengaged by the further decomposition of tarry matters, which would in some measure interfere with the operation, and prevent the salt solidifying; and should the temperature be under the true medium, there will be a looseness of texture and an opacity in the salt greatly against its value in the market. As the attendant cannot conveniently ascertain the most suitable temperature, any scientific directions for that purpose would be lost upon him; he may, however, by simple means, discover what costly pyrometers might fail to demonstrate in his hands. A few drops of water should readily boil on the cover of the sublimer, and be pretty soon dissipated in vapor; but the evaporation should not be so rapid as to indicate that the heat was approaching to redness; neither ought the heat to be so far raised as to cause a drop of liquor to dance about, out of contact with the iron. A short practice and attentive observation will enable the operator to govern the fire with effect. The top of the sublimer is invariably covered with some non-conducting material, that the caloric may be economized as much as possible.

Fig. 115



As the size of the sublimers varies, as above stated, so also does the amount of the charges, being from half to two or two and a half tons weight of the salt; the former is sufficient for the sublimers of three feet diameter, and the latter for those which are nine feet; sublimers of five feet diameter generally require from fifteen to eighteen hundredweight of the salt.

In consequence of chloride of ammonium still retaining some traces of water, even after the torrefaction in the drying furnace, and as it is liable to absorb a little from the atmosphere while the workmen are transferring it to the sublimers, the first coating of the salt in contact with the cover is always brownish. Several reasons might be assigned for such an effect: firstly, the moisture condensing upon the head, and softening any trace of oxide, would cause it to sink into the layer of salt that deposits thereon; secondly, decomposition of any resinous matters not completely destroyed in the drying furnace, whereby oily vapors would be liberated; and lastly, the presence of the sesquichloride or protochloride of iron. The effect of the latter, however, is not immediately on the first layer, but more generally afterwards, when a higher temperature pervades the whole.

The termination of the sublimation takes place in from five to nine days; but it is customary to raise the caps every week, the fire being checked for some hours previous to this. The salt is not completely sublimed, because the temperature required to expel the whole would cause the decomposition of the carbonaceous impurities, and emit vapors which would destroy in a great measure the beauty of the article. When a low heat is communicated, or the compound consigned to the subliming furnaces is impure, the chloride does not assume that compactness of grain which conduces to its transparency, but forms a kind of effloresced mass, though retaining the fibrous construction of the better quality. When the sublimation has reached as far as is desirable, the fire, as already stated, is allowed to go out, that the apparatus may cool; the cover is then removed by means of the tackle before noted, and there is found in the interior a hard lining of the salt, from two and a half to three or four inches thick; this is detached and conveyed to the packing-house or store, and the residuary matter remaining in the body of the sublimers is removed to another part of the factory to be converted into sulphate of ammonia. The business of the packing-house is to separate from the cake the brown coating arising from contact with the iron, and the causes before alluded to, by means of axes, after which it is broken up into convenient pieces, and packed in casks and barrels for market. Messrs. KURTZ, CROPPER, and Co., prepare during the winter months about fifteen tons weekly of the impure chloride, part of which is sublimed, so that, on an average, about six to eight tons of the latter are weekly ready for the market: the remainder of the impure salt is used for the preparation of sesquicarbonate of ammonia, or other salts of this alkali. The greater part of the chloride of ammonium is employed by color-makers and calico-printers, and by metallurgists for galvanizing iron.

SULPHATE OF AMMONIA.—Sulphate of ammonia is obtained at the above-mentioned factory by the following process:—A large pipe, connected with the main liquor tank, mentioned in the foregoing pages, conveys a quantity of liquor to a large boiler in the part of the factory appropriated to the making of this article. The boiler is placed over a fire, the flue from which circulates round the bottom and sides; a large pipe issues from its upper surface top, and descends through an adjoining tun, containing sulphuric acid, to its bottom. By bringing the contents of the boiler to ebullition, the free ammonia is driven off through the pipe into the tun containing the acid; here it is absorbed by the sulphuric acid, giving rise to sulphate of ammonia. Distillation is continued till no more ammoniacal vapors are eliminated, and then the fire is checked, while the residual liquor is drawn off and mixed with cream of lime, to give it a strong alkaline reaction; the whole is then run into a second and larger boiler, like the preceding, on the principle of a still; under this a brisk fire is applied, and the ammoniacal vapors liberated by the action of the lime are transmitted through the sulphuric acid solution in the tun. After all the ammonia is obtained, the waste liquor is run off.

During the time the alkaline vapors are blown through the sulphuric acid liquor, much water is removed from the solution, by the heat from the steam and ammoniacal gas, so that, in further concentrating the liquor, less fuel is required. The evaporating pans are similar to those used for boiling down the chloride of ammonium solution; but much more care is requisite when fire is applied directly to the pans, than when the concentration is effected at a steam heat; for the organic matter which the liquor contains partially decomposes the sulphate into hyposulphite or sulphide, which reacts upon the iron pans, or by the excess of acid present is decomposed, giving off sulphurous acid or sulphide of hydrogen gas. The overseer should be careful in observing if any traces of an odor resembling that of rotten eggs, which characterizes sulphide of hydrogen, become sensible, this tells that the decomposition is taking place, and of course admonishes him that it should be prevented by immediately withdrawing the fire or slacking it. Crystallized sulphate of ammonia obtained in the first operation, is much purer than the chloride of ammonium already described, in consequence of the impurities of the crude liquor being removed by the distillation. After the crystallization, the crude liquor which is still acid is returned to the tun, to combine with further quantities of ammonia.

Besides the ordinary liquor, the impure chloride from the packing-house and the refuse of the sublimers are sometimes decomposed by lime, as in the preceding case, and the eliminated ammonia transmitted through the acid solution to form sulphate; but they are generally used to prepare the carbonate. The sublimation of the crystallized sulphate cannot well be effected; but chloride of ammonium may be prepared from it, by mixing it with a proportionate quantity of chloride of sodium, and then heating; the chloride is sublimed, and sulphate of soda remains in the bottom of the sublimer.

About six tons are manufactured weekly by Messrs. KURTZ, CROPPER, and Co., and from a million and a half to two million gallons of ammoniacal liquor are worked up annually. In subliming ammoniacal salts, considerable advantage results from the use of large vessels, as the labor of attending them is in a great degree lightened, and the fire which is requisite to heat an apparatus of three feet in diameter, would serve, with very little addition, to sublime the contents of one of nine feet; the time required also in working the charge of each sublimer, whether it be three, five, or nine feet diameter, is nearly the same, though the quantity of salt produced by the larger ones is very different. They have been used with satisfaction in the form described; but a further advantage would be gained by having the bottom—instead of being flat, as is the construction at present—rising in a slanting direction from the sides to the centre. In this way the heat would be sooner communicated to the whole of the material introduced, and the time required for sublimation would be shortened. Ammoniacal gas liquor yields from three-quarters to one pound and a quarter of salt per gallon of liquor, but this quantity is subject to much variation from many causes.

In the manufacture of chloride of ammonium, as already described, if the purification of the liquor be not effected before crystallizing the salt, some traces of protochloride of iron are generally present, and often it is found in large proportions. When the crystals are submitted to the heat in subliming, the chloride of iron is volatilized, and is blended with the ammoniacal salt in the colorless as well as in the dark or brown seams of the cake.

Wurtz, who examined this substance, states that neither the brown nor colorless portions of the sublimate give any indications of iron, with the usual reagents, until nitric acid has been added to convert the protosalt of iron into the sesquisalt, after which the blue precipitate, or coloration, with ferrocyanide of potassium, and the red with the sulphocyanide of potassium, become very distinct. It was not generally considered that the colorless chloride of ammonium contained iron, till the above-named chemist noticed it. It seems that, although the iron might be present originally in the lie as a sesquisalt, it is subsequently converted into a protosalt by the reducing power of chloride of ammonium. The reaction may be represented as follows:—

$$\underbrace{Fe_2\,Cl_3}_{\text{Sesquichloride of iron.}} + \underbrace{N\,H_4\,Cl}_{\text{Chloride of ammonium.}} = \underbrace{2\,(Fe\,Cl)}_{\text{Protochloride of iron.}} + \underbrace{2\,H\,Cl}_{\text{Hydrochloric acid.}} + \underbrace{N\,H_2}_{\text{Amidogen.}}$$

or—

$$\underbrace{3\,(Fe_2\,Cl_3)}_{\text{Sesquichloride of iron.}} + \underbrace{N\,H_4\,Cl}_{\text{Chloride of ammonium.}} = \underbrace{6\,(Fe\,Cl)}_{\text{Chloride of iron.}} + \underbrace{4\,(H\,Cl)}_{\text{Hydrochloric acid.}} + \underbrace{N}_{\text{Nitrogen.}}$$

In either case, the sesquichloride of iron is converted into the protochloride.

Repeated crystallizations might remove the iron compound, but this would cause a loss of time, fuel, and material. By following **Brewer**'s method, the smallest trace of this salt is separated without involving any additional expense. His process consists in passing a few bubbles of chlorine gas through a concentrated hot solution of the salt in the crude state, which converts the protochloride of iron into a sesquichloride; this in turn is decomposed by free ammonia, with the precipitation of hydrated sesquioxide of iron, and the formation of chloride of ammonium. The liquor is kept hot for some time, till the whole of the flocculent brownish matter settles to the bottom, after which it is rapidly filtered and set aside to crystallize. By this means a perfectly pure salt, free from the least trace of iron, is obtained. Great care should be taken to keep the solution hot during the time the chlorine is being transmitted through it, and also not to prolong the action, in order to prevent the formation of the well-known dangerously explosive mixture—chlorhydride of nitrogen—

$$N\,Cl_3,\ N\left\{\begin{matrix}H\\Cl_2\end{matrix}\right.$$

The action of the chlorine in the first instance is represented by the equation:—

$$\underbrace{2\,(Fe\,Cl)}_{\text{Protosalt.}} + Cl = \underbrace{Fe_2\,Cl_3}_{\text{Sesquisalt.}}$$

and that of the ammonia, in precipitating the sesquioxide of iron from the latter, is thus:—

$$\underbrace{Fe_2\,Cl_3}_{\text{Sesquichloride of iron.}} + \underbrace{3\,N\,H_4\,O}_{\text{Ammonia.}} + \underbrace{3\,H\,O}_{\text{Water.}} = \underbrace{(Fe_2\,O_3,\,3\,H\,O)}_{\text{Sesquioxide of iron.}} + \underbrace{3\,(N\,H_4\,Cl)}_{\text{Chloride of ammonium.}}$$

The specification of Mr. **Croll**'s patent gives the following instructions for the preparation of ammoniacal salts:—A vessel, similar to those used for purifying coal gas by means of moistened quicklime, is filled with a solution of chloride of manganesium, made by dissolving one hundredweight of that salt in forty gallons of water, and the gaseous ammonia, generated in the usual way, is passed through it by the pressure from the retort. The manganic solution absorbs the ammonia, which precipitates a corresponding proportion of oxide of manganesium, and, as soon as fully saturated, it is drawn off, and a fresh charge introduced.

When sulphuric acid is combined with the alkali, a vessel, similar to that for washing the gas, is used, the sulphuric acid being of specific gravity 1·845, and in the proportion of two pounds and a half of acid to a hundred gallons of water. The gas is passed into it till the liquid marks a specific gravity of 1·170, when it is drawn off and a second charge supplied.

In preparing chloride of ammonium, the hydrochloric acid is taken at a density of 1·165 before diluting it, and then charged with the vapor till the gravity is 1·176; the proportion is the same as with sulphuric acid. In the preceding case of the manganese salt being used, the ammoniacal compounds are purified by filtering off the solution from the precipitated oxide, evaporating the filtrate, and subliming the residue. Sulphate of manganese, or protochloride of iron, may be substituted for the chloride of manganesium. That portion of metallic oxide which remains, is again converted into a fit state to absorb fresh quantities of the alkaline vapor, by the following simple method:—To every three parts of this residue, four of common salt are added, and the mixture heated in a furnace to low redness, which is scarcely perceptible in the dark, for about two hours or longer. Forty gallons of water are then added to every hundred and forty pounds of this mixture, and the liquid thus produced absorbs ammonia very rapidly. The precipitate which falls, consequent on the retention of the ammonia, only requires to be dissolved in the acid, which is intended to form a combination with the alkali, to render it suitable to serve the intended purpose a second and a third time.

Messrs. **Phillips**, **Watson**, **Jonson**, and others, have secured patents at various times for the production of ammonia and ammoniacal salts, but these scarcely differ from the old method of decomposing the substances with an alkali, and distilling off the volatile compound. **Hill** proposes to convert the ammonia eliminated in the distillation of coals into chloride, by mixing chloride of manganesium with the coals in the retorts, or introducing the chloride into a retort appropriated for the purpose; the heat dispels the hydrochloric acid, and this, uniting with the alkaline vapor, forms chloride of ammonium, which is retained in the liquor in the condenser. After removing the tar in the usual way, the salt is obtained by evaporation and sublimation, as before described.

Spence recommends a series of cylindrical-covered boilers, or reservoirs, placed at such different elevations that the contents of the uppermost may be drawn off into the next, and so on in succession to the lowest, as an economical arrangement in preparing chloride of ammonium, or sulphate of ammonia, from gas liquor, *et cetera.* Each boiler has an exit pipe, which carries the vapor generated in it to that which is next above it, and the exit pipe of the highest boiler passes off to a tank, where the acid requisite to form the salt is supplied. A charging pipe connects the top boiler with the reservoir of gas liquor, which is already mixed with milk of lime, and by turning a stopcock attached to it the boiler may be replenished. Four boilers are deemed sufficient, but a larger number may be used. A pipe, conveying high-pressure steam, enters the lower boiler, by which the liquid is made to evolve its ammonia into the next boiler; and in the same manner the contents of this and the upper boilers are brought to the temperature of ebullition, the ammonia passing through each by the connecting pipes, till it is expelled from the highest, in a very concentrated state, to the acid tank. When moderately concentrated acid is used after the absorption of the ammonia in the series of boilers, the lie is so strong that it may be drawn off at once to crystallize. As the liquor in the lowest boiler becomes exhausted of its ammonia, the fire is slackened and the contents run off, and that of the next boiler admitted instead; the latter is supplied from the one above it, and so on to the highest, which is filled from the reservoir. When the boilers are replenished, the fire is stirred up, and the distillation proceeded with as before. The solution of chloride of ammonium, or sulphate of ammonia, is treated in the usual way for obtaining the dry salt.

Salts of ammonia are prepared from guano in the manner specified by **Turner**, under the patent which he obtained in 1844 for this purpose. The guano is subjected to destructive distillation in close iron cylinders, at a low red heat during the greater part of the operation; this temperature is increased towards the end. The eliminated gases are made to pass through three Woulfe's bottles, or vessels arranged on that principle, in order that the whole of the condensable products may be retained. Carbonate of ammonia, hydrocyanic acid, and carbide of hydrogen, are copiously disengaged; the first two, being rapidly absorbed, give a strong solution of cyanide of ammonium and of carbonate of ammonia, while the carbide of hydrogen passes into the atmosphere.

As soon as the charge of the retorts has been exhausted, the solution in the condensing apparatus is drawn off, and mixed with as much protochloride of iron as is necessary to precipitate the whole of the hydrocyanic acid in the form of prussian blue. In consequence of the free ammonia present, the blue precipitate does not appear on adding the iron salt, but on neutralizing this ammonia with hydrochloric acid, it then falls down of a fine blue color; this is filtered off and well washed, after which it is converted into ferrocyanide of potassium—*yellow prussiate*—by boiling with potassa, evaporating the solution, and crystallizing in the usual way. If an excess of iron is present in the liquid filtered from the iron precipitate, it is separated by adding carefully a fresh quantity of the ammoniacal solution, which precipitates it, and it is then removed, and the neutral solution of chloride of ammonium evaporated. Sulphate of ammonia is procured in a similar manner, by employing sulphuric instead of hydrochloric acid, and sulphate of iron instead of the chloride.

By the action of sulphuric or hydrochloric acid upon stale urine, corresponding salts of the alkali are obtained by simply evaporating the solution, and crystallizing.

Peat is a substance which is rich in ammonia, and therefore the fabrication of ammoniacal salts from this source is one of the principal features in the works of the British and Irish Peat Company.

Reece directs, in the patent which he secured in 1849, that the peat should be carbonized in a blast furnace, and the combustible gases and volatile substances, given off during the ignition, conducted to a suitable condensing apparatus appended, wherein the tar, ammoniacal carbonate, naphtha, and other condensable compounds are retained. The tar is subsequently separated and employed for the production of paraffine and oil; the ammoniacal liquid is neutralized with an acid, then distilled, to procure the naphtha, and the residual product evaporated in the usual way.

According to the scientific statements which have been drawn up at various times by Sir **Robert Kane** and others, peat yields from twenty-two to twenty-five pounds of ammoniacal salts per ton, so it appears the dividends accruing to the company are pretty satisfactory.

For the preparation of the chloride or sulphate, **Laming**'s patent, obtained in 1850, claims the application of certain salts and compounds which are to be used in the purifiers of the gas-works, and through which the gases given off from the retorts are transmitted, so as to retain the ammoniacal vapor; these substances are chloride of iron, decomposed by hydrate of lime into oxide, with the formation of chloride of calcium; also the use of sulphate of iron, which he converts, by means of chloride of sodium, into chloride of iron and sulphate of soda; and the chloride thus prepared is then decomposed, as in the preceding instance, into oxide of iron and chloride of calcium. Further, the patentee claims the use of a mixture of sulphate of lime and sulphate of iron, or of the precipitated hydrated oxide of iron with carbonate of lime, magnesia, carbonate of magnesia, or magnesian limestone; of chloride of magnesium, or sulphate of magnesia and water; of phosphate of lime dissolved in hydrochloric acid; and of a mixture containing sulphate of magnesia, or chloride of magnesium or calcium, or one or more of these, in combination with oxide of copper, and mixed or not with lime or magnesia, or both or either, or both of the carbonates of those earths. In all of these cases, the salts or mixtures employed are mingled with sawdust, or some porous substance, before being placed in the purifying vessel. After they become saturated with the vapor of ammonia, the chloride or sulphate formed is removed by simply washing the mass with water. In his patent for 1852, he claims the use of sulphurous acid as a means of preparing sulphate of ammonia, and proceeds as follows:—The ammonia is liberated in the free state or as carbonate, by any simple means, and received in water; and by a stream of sulphurous acid gas, which he transmits through this ammoniacal liquid, forms sulphite of ammonia; finally, he oxidizes this salt into sulphate by agitation and exposure to the air.

Another patent was granted to MICHIEL in 1850, for his improved method of preparing sulphate of ammonia by means of sulphate of lead, containing an excess of oxide.

On submitting such compounds to the ammoniacal solutions, decomposition of the lead salt takes place, being converted partly into sulphide, and partly into a carbonate, which will be found suitable for many manufacturing purposes, while a sulphate of ammonia results. He prepares the oxysulphate in the following manner:—Native sulphide of lead is ground into small fragments; the reduced mass is then spread upon the higher of two shelves, constructed in a reverberatory furnace, where it is heated for about two hours. It is then drawn off to the under bed or shelf, where it is more strongly heated, and kept occasionally stirred to prevent fusion or caking of the mass, and also to have every part equally heated. The second heating effects the transformation of a portion of the sulphide into sulphate, while another part is oxidized and sulphur eliminated. The layer of galena is about two to two and a half inches in depth.

In December of the year 1850, Mr. WILSON secured another patent for preparing sulphate of ammonia from the waste products of coke ovens, *et cetera.* His method consists in transmitting the vapors through a circular tower, filled with coke pebbles, or other disintegrated bodies. A cistern at the base of the tower is filled with sulphuric acid, so diluted that, when completely saturated with ammoniacal vapor, the heat of the apparatus will not concentrate it so much as to deposit crystals of the salt. Another cistern, similar to the preceding, is placed on the top of the tower, the bottom of which is perforated. All the vapors from the ovens are forced through the lower cistern and up the tower, and, by an arrangement which continually raises the dilute acid liquor of the lower tank to the upper, so that it falls again through the perforations, any of the alkali that may escape combination from the cistern is taken up by the trickling solution in the body of the cylinder.

By filtration, evaporation, and crystallization, the sulphate of ammonia is obtained from the solution after the acid employed has been neutralized.

Dr. RICHARDSON prepares the sulphate of ammonia by forming a double sulphate of magnesia and ammonia, and afterwards submitting this product to sublimation.

SESQUICARBONATE OF AMMONIA.—This compound of ammonia is prepared, on the large scale, by heating chloride of ammonium, or sulphate of ammonia, and chalk, in close vessels; double decomposition of the two compounds follows, which causes the formation of sesquicarbonate of ammonia, and a salt of lime analogous to the ammoniacal one taken. Three equivalents of the ammoniacal salt react upon three equivalents of chalk or carbonate of lime, and the result is one equivalent of sesquicarbonate of ammonia, one of free ammonia, and three equivalents of a lime salt, thus:—

$$\underbrace{3\,(\mathrm{N\,H_4\,Cl})}_{\text{Chloride of ammonium.}} + \underbrace{3\,(\mathrm{Ca\,O,\ C\,O_2})}_{\text{Carbonate of lime.}} = \underbrace{(2\,\mathrm{N\,H_4\,O},\ 3\,\mathrm{C\,O_2})}_{\text{Sesquicarbonate of ammonia.}} + \underbrace{\mathrm{N\,H_4\,O}}_{\text{Ammonia.}}$$
$$+ \underbrace{3\,\mathrm{Ca\,Cl},}_{\text{Chloride of calcium.}}$$

or—

$$\underbrace{3\,(\mathrm{N\,H_4\,O,\ S\,O_3})}_{\text{Sulphate of ammonia.}} + \underbrace{3\,(\mathrm{Ca\,O,\ C\,O_2})}_{\text{Carbonate of lime.}} = \underbrace{(2\,\mathrm{N\,H_4\,O},\ 3\,\mathrm{C\,O_2})}_{\text{Sesquicarbonate of ammonia}} +$$
$$\underbrace{\mathrm{N\,H_4\,O}}_{\text{Ammonia.}} + \underbrace{3\,(\mathrm{Ca\,O,\ S\,O_3})}_{\text{Sulphate of lime.}}$$

The above decomposition may appear at a glance to be at variance with the general composition of bodies resulting from the mutual action of neutral salts, such as those taken in the preceding instance; for, conformably with the general behavior of the double decomposition of neutral compounds, it would be supposed that the change in the preceding would be—

$$\underbrace{3\,\mathrm{N\,H_4\,Cl}}_{\text{Chloride of ammonium.}} + \underbrace{3\,(\mathrm{Ca\,O,\ C\,O_2})}_{\text{Carbonate of lime.}} + \underbrace{3\,\mathrm{H\,O}}_{\text{Water.}} = \underbrace{3\,(\mathrm{N\,H_4\,O,\ C\,O_2,\ H\,O})}_{\text{Neutral carbonate of ammonia.}}$$
$$+ \underbrace{3\,\mathrm{Ca\,Cl}}_{\text{Chloride of calcium.}}$$

producing a carbonate of the oxide of ammonium and chloride of calcium, both of which are neutral bodies. According to the experiments of ROSÉ, it appears that the neutral carbonate of ammonia does not exist, *per se;* hence, even should it be produced at the first application, decomposition would immediately take place, and cause the evolution of gaseous ammonia and water, corresponding to $\mathrm{N\,H_4\,O}$, or $\mathrm{N\,H_3,\ H\,O}$.

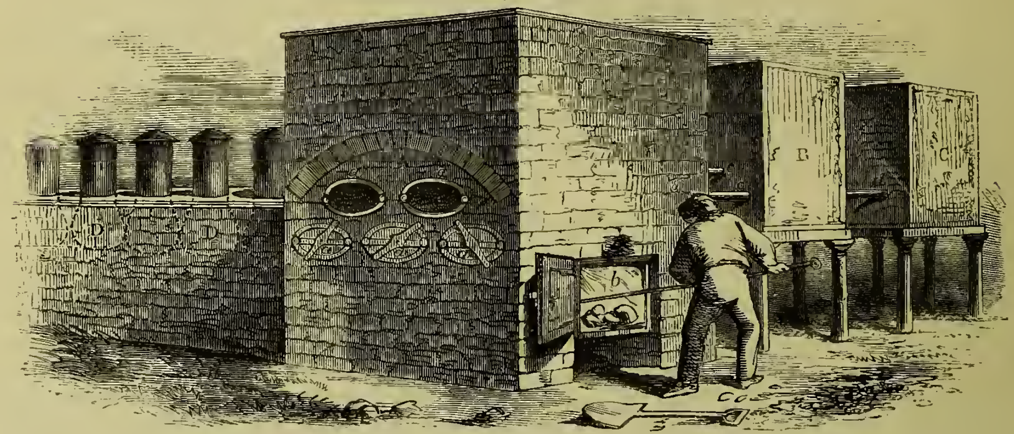
Leaden chambers are used as condensers to retain the volatilized salt from the heated retorts; they generally have the top or bottom partly movable, or have a door in their sides, to allow of the removal of the salt. The crude sesquicarbonate obtained in the first sublimation, is purified by expelling it by heat from iron pots, surmounted by leaden caps. The waste heat of the flue from the furnace which heats the retorts, serves for this part of the work. In the second operation, water is added to render the salt translucent.

The annexed woodcut—Fig. 116—represents such an arrangement as is here mentioned. In this figure the retorts are cylindrical, and laid horizontally in the furnace, similar to those used in the carbonization of wood for the production of wood vinegar, having the exit pipe for the passage of the sublimed salt at the back; or they may be like those already described in the distillation of bones.

A is the exterior of the furnace containing the five retorts, *a a a a a*, laid horizontally, and closed at the front by iron doors made secure by bolts and screws.

Heat is communicated by the fire, *b*, at the end of the furnace. The pipes, *c c*, carry off the vapors of carbonate of ammonia into the chamber, B, and whatever remains uncondensed in this is discharged into a second one, C, by the connecting pipe, *d*. Both chambers are supported upon pillars or scaffolding, to bring them on a line with the retorts; D D, are the purifying pots, made of cast-iron, and surmounted with leaden heads, into which the carbonate is volatilized from any fixed impurities by the heat of the flue from the fire, *b*.

Fig. 116.



One part of sulphate of ammonia, or chloride of ammonium, mixed with one and a half or two parts of carbonate of lime, is introduced into the retorts, and a moderate heat applied at first, which is gradually increased towards the end of the operation. The vapors which are eliminated through the pipes, *c c*, in the figure, are condensed in the chambers, B and C. After the charge in the retorts becomes exhausted, the salt condensed in the chambers is removed to the purifying vessels, D D, where it is sublimed at a low degree of heat; sometimes 150° Fahr., communicated by a water-bath, is found to answer the purpose.

Laming recommends, for the preparation of sesquicarbonate of ammonia, the conveyance of the constituent gases into a series of leaden chambers, on a large scale, the temperature of which should be kept as low as practicable, in order to induce as much as possible the combination of those gases. It is unnecessary to have them in atomic volumes; in fact, it is desirable that the carbonic acid should be in excess.

A stratum of water, or of a solution of ammonia, is supplied in one or other of the chambers, and in this case the resulting product is said to contain more carbonic acid than when the gases unite as they issue from the vessels where they are generated.

The solution is evaporated, and the salt purified by sublimation.

The same chemist prepares carbonate of ammonia from sulphide of ammonium found in gas liquor, by a novel process. Oxide of copper and charcoal are used in the proportion of twelve parts of the former to one of the latter; and this mixture is introduced into any suitable retort—cast-iron—wherein it is heated to redness; the pipe, joining the beak, passes through cold water previous to its entrance into the ammoniacal solution of the sulphide or the gas liquor. The action of the heat upon the oxide of copper and charcoal gives rise to carbonic acid, which, entering into the solution, displaces the sulphur in combination with the ammonium, and causes it to be dispersed as sulphide of hydrogen, while the carbonic acid takes its place, and a solution of carbonate of the alkali is formed.

When the carbonic acid ceases to be eliminated, the whole of the oxide is reduced to finely-divided metallic copper, and very little, if any, charcoal remains. The retort is cooled, and the contents drawn out, while another retort, similarly employed, maintains the stream of carbonic acid through the solution. During the cooling of the contents of the first retort, the finely-divided copper, by uniting with oxygen from the atmosphere, is reconverted into protoxide, which may be used over again with a fresh portion of charcoal; and so on, till the elimination of sulphide of hydrogen ceases, at which period the liquor is known to be saturated with the carbonic acid gas.

Crane and **Julien** direct, for the preparation of carbonate of ammonia, cyanide of ammonium, or the free alkali, from any of the oxides of nitrogen, that a carbide of hydrogen gas should be brought into contact with such oxides in the presence of a body which may induce combination by means of contact. For this purpose they give preference to platinum-sponge; or asbestos coated with platinum foil answers the purpose. The platinum is placed in the calibre of a large tube, heated to about 600° Fahr., to reduce the temperature of the gases, and at the same time prevent the deposition of the carbonate of ammonia formed on the tube, and cause it to be forced onwards to a condensing medium. Any gases uncondensed in the carbonate of ammonia chamber, are made to traverse a solution of ammonia, or of iron, for the purpose of retaining the hydrocyanic acid collaterally formed.

Sesquicarbonate of ammonia is a white fibrous substance, found sometimes in the market in translucent cakes, of about two inches in thickness. It is soluble in four parts of water at 55° Fahr., in 3·3 parts at 62°, in 2·7 at 90°, in 2·4 at 105°, and in two parts at 120°.

On exposing this solution to the air, decomposition takes place, ammonia and carbonic acid are evolved, and a bicarbonate remains.

$$2\,\underbrace{(2\,NH_4O,\ 3\,CO_2)}_{\text{Sesquicarbonate.}} = 2\,\underbrace{(NH_4O,\ CO_2)}_{\text{Neutral salt.}} + 2\,\underbrace{(NH_4O,\ 2\,CO_2)}_{\text{Bicarbonate.}}$$

As already stated, the neutral carbonate does not bear exposure to the air without decomposing into ammonia and carbonic acid; hence the ammoniacal odor emitted from the sesquicarbonate of ammonia. Bicarbonate of ammonia, remaining after the exposure of the sesquicarbonate, is not so pungent as the salt which produces it. Medically, it is known as mild carbonate of ammonia. It yields a precipitate with bichloride of platinum in the presence of hydrochloric acid; with copper salts, it gives the characteristic blue color produced by ammonia; with the salts of the alkaline earths, it does not yield an immediate precipitate; on boiling the mixture, however, the insoluble earthy carbonate falls down.

The composition of the sesquicarbonate of ammonia, according to the analysis of PHILLIPS and ROSÉ, is annexed:—

		Centesimally represented.			
	At. weight.	Theory.	Phillips.	Rose. I.	Rose. II.
3 Eqs. of carbonic acid,...	66	55·93	54·2	50·55	53·4
2 Eqs. of ammonia,.......	34	28·81	29·3	28·66	30·7
2 Eqs. of water,.........	18	15·26	16·5	20·79	15·9
	118	100·00	100·0	100·00	100·0

ROSÉ states that the composition of the sesquicarbonate varies with the mode of preparing it. When obtained by the sublimation of the salt from chloride of ammonium—or any other compound of ammonia—and carbonate of lime, the product is a scsquisalt; but on subsequent sublimation, for the purpose of purifying, he says that it is only four-fifths sesquicarbonate, as his analysis indicates:—

		Centesimally represented.	
	Atomic weight.	Theory.	Found.
4 Eqs. of ammonia,........	68	31·78	31
5 Eqs. of carbonic acid,.....	110	51·40	51
4 Eqs. of water,...........	36	16·82	18
	214	100·00	100

SCANLAN is of opinion that the compound regarded as the sesquicarbonate of ammonia, is only a mixture of anhydrous carbonate and bicarbonate of ammonia; because, on washing sesquicarbonate with cold water, the bicarbonate of ammonia remains under the same physical form as the salt submitted to edulcoration, while the neutral carbonate is abstracted; further, he employs the formula $(NH_4O,\ CO_2 + NH_4O,\ 2\,CO_2)$ to represent the sesquicarbonate, on account of the preceding behavior. The opinion of PEREIRA is opposed to these, for he assumes it to be a true chemical compound, both from its uniformity of composition, when prepared in the same way, and its crystalline structure; besides, he thinks the above representation of SCANLAN to be less probable, because the anhydrous neutral carbonate is dissipated upon exposure of the salt to the air, and the bicarbonate always contains water. The Editor considers the view of ROSÉ the correct one. Sesquicarbonate of ammonia possesses a pungent odor, a hot and saline taste, and a powerful alkaline reaction; it is used in medicine as a stimulant and antacid, and is a useful source of other ammoniacal salts. Bicarbonate of ammonia crystallizes from the hot concentrated solutions of the sesquicarbonate, or it may be precipitated by alcohol; by the action of heat upon the sesquicarbonate, decomposition into various compounds, with more or less carbonic acid, ensues; the sesquicarbonate of commerce is a mixture of several of these.

The impurities of the sesquicarbonate are organic matter and small portions of the salt submitted to decomposition with chalk, which pass over to the chambers unchanged; sometimes it may contain hyposulphite of ammonia, arising from the decomposition of the sulphate of ammonia, when this salt has been used, and also traces of lead, derived from the leaden chambers.

Organic matter is detected simply by dissolving the commercial article in water, when a solution of a brownish or even blackish color is produced, while the pure salt affords a colorless liquid. Sulphates or chlorides are detected by dissolving the substance in water, adding a few drops of nitric acid, and dividing the solution into two portions; to one part chloride of barium is to be added, and to the other a few drops of nitrate of silver solution; a white precipitate in these menstrua shows the presence of sulphuric acid in the former, and of hydrochloric acid in the latter.

Hyposulphites are detected by dissolving a portion of the salt in acetic acid, and adding nitrate of silver; a precipitate is obtained, which is white at first, but soon turns black, in consequence of the oxide of silver being reduced by the deoxidizing effects of the hyposulphurous acid. Lead is detected by transmitting a stream of sulphide of hydrogen gas through a solution of the salt, which occasions a black precipitate, or coloration, if lead be present.

Acetate of Ammonia has been already described under Acetic Acid, see page 38.

In agriculture the salts of ammonia are most valuable, increasing in a remarkable manner the fertility of the land, provided the other constituents peculiar to the crop be present; hence they are to be found in all good manures, the value of which they greatly enhance. Ammonia constitutes one-fifth of the weight of genuine Peruvian guano; stable manure also yields it in large quantities, and it is one of the valuable ingredients of bone manure. Salts of ammonia are extensively used in calico-printing, in the preparation of leather, and in pewtering; in the latter, as well as in tinning sheet-iron and iron vessels, the chloride is preferred; and from its volatility, by which it excludes the air, and thus prevents the oxidation of the tin, it is productive of the greatest benefit in this art.

ESTIMATION OF AMMONIA.—To the manufacturer who employs ammoniacal salts, it is very necessary that he should be able to ascertain their purity, so as to know their real value, and what amount of work he can perform with their aid; but it concerns the agriculturist particularly, to ascertain the quantity of ammonia which may be contained in the different kinds of manure he lays upon his land, with the hope of reaping thereby a rich harvest. It is still more especially the province of the amateur and professional chemist to know how to determine the per centage of this alkali, whether in soils, manures, or other compounds capable of affording it. To meet these requirements for the reader who may not be already conversant with such processes, the Editor subjoins the following instructions for his guidance.

Ammonia is determined, for the most part, either as chloride of ammonium, or as the double chloride of ammonium and platinum. The ammonia, in complex organic bodies, is sometimes ascertained indirectly from the volume of nitrogen which they afford, when such substances are treated as will be further described.

As Chloride.—In pure solutions of ammonia, carbonate of ammonia, or any other of its combinations with a feeble volatile acid, the alkali is invariably determined by saturating with hydrochloric acid, and evaporating the solution to dryness in a water-bath, till the whole of the free acid and moisture are removed; the dry residue, accurately weighed, gives the amount in the form of chloride of ammonium. Should the solution contain only chloride of ammonium, evaporation of the water and weighing of the dry residue will give at once the amount of that salt, from which the ammonia contained therein is calculated. If the substance be solid or liquid, in either case a certain portion is weighed, say thirty grains of the solid, and one thousand grains of the liquid; the former in a crucible or covered watch-glass, and the latter in a perfectly clean and dry beaker-glass, which should be rather small, and tared accurately before introducing the liquid. After the solid has been dissolved in water, the succeeding treatment is the same as with the solution; hydrochloric acid is added in very slight excess, and then it is to be evaporated carefully, so as not to cause spirting, neither should the vessel be exposed to dust or other accidental impurities. The evaporation is best conducted in a platinum dish, and when no further loss is sustained by heating in the water-bath, the dish and dry residue are weighed; the difference between this weight and that of the dish is the weight of the chloride of ammonium. If a platinum vessel be not at hand, the evaporation may be continued to dryness in the beaker-glass wherein the solution was originally taken, provided it be small, and the beaker and its contents weighed, as in the foregoing instance; but if this should not happen, when the greater part of the water has been driven off, the concentrated liquor is to be carefully transferred to a platinum crucible, or small thin porcelain dish, and also the washings are to be gradually added, the solution evaporated to dryness, and the perfectly dry mass weighed. When the weight of the vessel is deducted from the combined weight, the difference is, as before, the chloride of ammonium. Very accurate results are in this way arrived at, if ordinary care has been exercised, as the trace of chloride which escapes during the evaporation is almost imperceptible. With a similar degree of accuracy, the ammonia may be determined by substituting sulphuric acid for the hydrochloric, and proceeding as above; the ammonia is calculated from the weight of the sulphate. In 53·5 parts of chloride of ammonium, there are seventeen of gaseous ammonia, or twenty-six of the oxide of ammonium, so that by simple proportion the per centage of ammonia is found, thus:—If the above weight yielded twenty-five grains of the chloride, the calculation will be,—as 30 : 25 :: 100 : 83·33; and as 53·5 of the chloride contains 17 of gaseous ammonia, equal to 26 of the oxide, the next statement will be,—as

$$53{\cdot}5 : \left\{\begin{array}{c}17\\ \text{or}\\ 26\end{array}\right\} :: 83{\cdot}33 : \left\{\begin{array}{l}26{\cdot}47 \text{ per cent. of the gaseous body, or}\\ 40{\cdot}42 \text{ `` `` of the oxide.}\end{array}\right.$$

In 66 parts of dry sulphate of ammonia there are likewise contained 17 of dry gaseous ammonia, or 26 of the alkali; the amount of ammonia in the sample, when sulphuric acid is used, is determined similarly to the example given.

As a double salt of Ammonium and Platinum.—In this form, all those salts of ammonia which are soluble in alcohol may be determined by converting them into a chloride by the addition of an excess of hydrochloric acid, and evaporating to dryness; then, on dissolving the dry mass in a small quantity of water, and precipitating by a solution of bichloride of platinum in excess, a yellow crystalline deposit forms, which is the compound salt. The menstruum is carefully evaporated to dryness at 212° Fahr., the dry mass treated with a little alcohol, and then thrown upon a filter, where it is washed with alcohol till the filtrate ceases to have a yellow color, which the first washings possess, owing to an excess of bichloride of platinum. Should the filtrate not be colored, it shows that enough of the precipitant has not been used, and in such a case the operation is not satisfactory, and should be recommenced, taking care to have the bichloride in excess, which is known by carefully observing if the supernatant liquid, after the greater part of the crystals has fallen to the bottom, is of a yellow color; the salt is to be thrown upon a filter, and washed with alcohol as above directed. The filter should be carefully deprived of dust, dried at 212°, till the weight remains constant, before introducing the yellow crystalline compound; and after the substance has been thoroughly dried and weighed, the difference between the latter weighing of the paper and salt, and that of the paper alone, is the ammonia-platinum salt. Its constitution is the following:—

	Atomic weight.	Centesimally represented.
1 Eq. of ammonium,	18	8·06
1 Eq. of platinum,	98·6	43·03
3 Eq. of chlorine,	106·5	48·91
	223·1	100·00

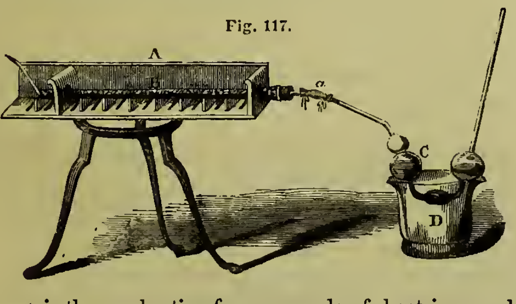
Formula: $NH_4Cl, PtCl_2$.

Hence every two hundred and twenty-three parts of the precipitate contain seventeen of dry ammonia, or twenty-six of the oxide of the metal ammonium; or, centesimally, about 7·62 of the gaseous body, or 11·65 of the oxide, so that, by the assistance of these data, it is easy to arrive at the proper quantity contained in the sample under examination.

As a check upon the determination, the platinum compound may be introduced into a counterpoised porcelain crucible, and heated gently to redness, by which all the other components of the precipitate, except the platinum, are expelled; this metal remains in the form of a black spongy powder, which is to be weighed, and from its quantity, the ammonia contained in the sample is calculated by the following proportion:—As $98{\cdot}6 : \left\{\begin{array}{c}17\\ \text{or}\\ 26\end{array}\right\} :: x$—the weight of the platinum found—$: y$—the corresponding ammonia; and then, as the weight of the compound taken $: y :: 100 : \frac{z}{y}$, the per centage of the alkali. During the ignition of the ammonio-chloride of platinum, the heat must be applied very gently at first, and the crucible kept covered, lest the too rapid evolution of chloride of ammonium should carry off some of the platinum, and give rise to an error. Towards the end of the operation the heat may be increased, and when no more vapors are observed, the crucible is allowed to cool, and then weighed.

When the ammoniacal compounds are insoluble in alcohol, they are analyzed by a more difficult way than either of the methods already described. The salt is ground with soda lime—a compound prepared by slaking pure caustic lime with a solution of hydrate of soda, of such strength that one part of the caustic alkali will be equal to two of the lime, after which it is heated in a Hessian crucible to dull redness, and then pulverized and retained for use in stoppered bottles—and the mixture heated in a combustion tube, in the same way as an organic analysis is conducted. A nitrogen apparatus—that recommended by Will and Varrentrapp—is connected to the end of the tube by the aid of a perforated cork, which fits the latter perfectly tight; the bulbs of the apparatus are filled with hydrochloric acid of 1·20 specific gravity, for the purpose of retaining the ammonia which is disengaged from the heated material in the tube. Fig. 117 shows the arrangement as here indicated.

Fig. 117.



A is the combustion furnace, made of sheet-iron, and resting upon a tripod, or it may be supported upon a table or cast-iron plate; B, the combustion tube, about sixteen inches in length, and made of hard German glass, which bears the high temperature without fusing. The diameter of the tube should be about three-eighths of an inch, and one end should be drawn out to a point, sealed at the extremity, as seen in the engraving. The mouth of the tube is closed by a perforated cork, into which a small tube is introduced, and which is connected to the nitrogen apparatus, C, by means of a caoutchouc connecter, *a*. The nitrogen apparatus has four bulbs, which are filled with hydrochloric acid to the level represented; the apparatus rests upon a convenient support, D. By placing the long limb of the bulbed tube in a small glass filled with the acid, and applying suction to the other end, it is readily filled to the proper height. Great care must be taken that too much acid is not admitted, as then there would be a risk of spoiling the analysis by the liquid flowing back into the combustion tube.

Before proceeding to the determination, the substance should be thoroughly dried, either in the water-bath, or over sulphuric acid in the exhausted receiver of an air-pump; ten to twenty grains are then taken, and mixed intimately with the soda lime in an agate or glass mortar, which should be placed upon a large sheet of glazed paper, to prevent the loss of any particles that may be accidentally dropped during the grinding and filling of the tube. As much of the soda lime is put into the tube as is sufficient to fill about three-quarters of an inch, and then the mixture of the substance under examination and the lime compound is introduced as speedily as possible. The mortar is rinsed with successive small quantities of the powdered soda lime, and these are added to fill up the empty part of the tube to within two inches of its mouth. A loose plug of asbestos is now inserted, and the cork with small tube tightly fitted to it; a space through which the products of the combustion may traverse the tube is made by holding the latter in the hand, and giving it a few gentle taps horizontally against the table; the contents aggregate more closely, and an empty space is formed in the upper part. The tube is now placed in the furnace with the pointed end upwards, as seen in the figure, and the nitrogen apparatus attached by means of the connecter. Care must be exercised that all the joinings are air-tight; this the operator may ascertain by holding a glowing piece of charcoal to the inner bulb, till a few bubbles of expanded air escape to the middle one; if, on removing the coal, the liquid assumes the original level the connections are air-tight. Red-hot pieces of charcoal are now applied to the posterior part of the tube for a short time, to expel the air contained in the apparatus; and after that, the pieces are placed at the front end, and gradually retire as the matter becomes decomposed, till the whole of the tube is at a low red heat. Particular pains should be taken to eliminate the ammonia gradually and steadily, and, above all, not to allow the heat to remain stationary at any part of the tube, till all the ammonia contained in that part is expelled; for on removing the coals a vacuum is formed, which causes the reflux of the hydrochloric acid from the nitrogen apparatus into the tube. Hence the coals should be applied to a fresh part, before the matter already decomposing is completely exhausted.

When no more ammonia is given off, the pointed end of the tube is broken by a forceps, and suction applied to the long arm of the nitrogen apparatus, in order to draw over the last traces of ammonia that might remain in the apparatus; after which it is detached, and the chloride of ammonium solution transferred to a beaker glass, or platinum dish, together with the water used to rinse the bulbs, and the whole evaporated to dryness.

The residue thus obtained is dissolved in as small a quantity as possible of distilled water, filtered from any residue which may happen to exist in it, and the filtrate and washings precipitated by bichloride of platinum; the solution is then evaporated, and treated with alcohol. The remainder of the operation is conducted in the same way as already described. The results, when the operation is carefully performed, are very accurate.

The preceding process may be shortened, by taking a known weight of the hydrochloric acid—the quantity of real acid in which may be ascertained both from the specific gravity, and from an acidimetrical examination —and after the ammonia from the mixture in the combustion tube has been absorbed, the contents of the nitrogen apparatus are transferred to a beaker glass, together with the washings, and the excess of acid neutralized with a standard solution of ammonia, of specific gravity ·992, containing one equivalent of ammonia in a thousand grains of the solution. According to the number of grains or measures from a burette, required to saturate the free acid, the quantity of ammonia in the sample is calculated. Thus, if 300 grains of acid of 1·20 density, which contain 40·70 per cent. of dry acid, were taken, and required, after the ammonia in twenty grains of the mixture was absorbed, 267¼ measures of the ammoniacal solution to neutralize it; and knowing that every hundred measures, or a thousand grains of the test liquor, contain an equivalent of the alkali, which is capable of neutralizing thirty-six and a half grains of real acid—one equivalent—the total weight of free acid taken up by the test liquor is ascertained by simple calculation, and this deducted from the real acid in the three hundred grains employed as above, the difference is what had been saturated by the ammonia in the sample; and as 36·5 of hydrochloric acid is equivalent to 17 of ammonia, the ammonia in the sample is calculated from these data; *videlicet*,

36·5 : 17 :: x—the acid taken up—: y—the ammonia in the sample;

and centesimally—

As 20—the number of grains of the mixture—: y :: 100 : y', the per centage.

A more delicate way by which the quantity of the excess of acid is found, is, according to PELIGOT, by dissolving caustic lime in a solution of sugar, and neutralizing the acid with the solution thus obtained. The liquid is preserved from contact with carbonic acid in well-stoppered bottles; should carbonic acid be absorbed, it causes a white precipitate of carbonate of lime, which may be removed by filtration, and the solution thus clarified serves the intended purpose.

The saccharate of lime thus formed has an alkaline reaction, and neutralizes acids like an alkaline carbonate. Its saturating power is tested by reducing pure concentrated sulphuric acid to a density of 1·25 by means of water, after which five hundred grains, or any convenient quantity, is taken, and the weight or measure of the saccharate of lime liquor necessary to neutralize it noted. By calculating from the specific gravity, the weight of dry acid present in the liquor taken for the experiment is found, which is equivalent to the volume of the test liquor acid, say one hundred divisions of the burette. These numbers will remain a constant factor as long as the saccharate of lime is made of a uniform strength, and, therefore, any amount of acid in a sample is proportionate to the number of divisions of the liquor required to saturate it, and may be calculated accordingly. To apply it to the foregoing experiment:—After the whole of the ammonia is absorbed, the content of the sulphuric acid dish is transferred to a tall testing glass, and the prepared liquor poured in from a burette, till the acid is exactly neutralized, which is known by a strip of litmus paper in the usual way, as well as from the bluish tint which the solution acquires. The number of measures of test solution used is read off; from these the quantity of dry acid remaining of the five hundred grains is found in the way already alluded to; and deducting this from the total weight of dry sulphuric acid, the difference will be the quantity taken up by the ammonia of the sample experimented upon, and which is found by calculation.

To give an example:—Let fifty grains of the sample be treated as directed in the foregoing, using three hundred grains, or any other convenient weight of the acid, of the normal density 1·137; and after the whole of the ammonia has been absorbed by the acid, the surplus of the latter requires, say sixty measures of the test liquor. Now, if it be previously ascertained what quantity of this test solution is required to neutralize one hundred grains of the acid of 1·137 density, equal to 27·72 of dry acid, which may be here taken as fifty, the free acid remaining of the three hundred grains above is easily found; for, as 50 : 27·72 :: 60 : 33·264; and this sum deducted from the dry acid, is the quantity of acid taken, *videlicet*, 83·16 = 27·72 × 3, the difference will be 50 in round numbers. It being known that forty parts of dry sulphuric acid combine with sixteen of gaseous ammonia, or twenty-six of the oxide, the corresponding weight of ammonia taken up by the fifty grains is found thus:—As

$$40 : \left\{\begin{array}{c} 17 \\ \text{or} \\ 26 \end{array}\right\} :: 50 : \left\{\begin{array}{l} 21{\cdot}0 \text{ of gaseous ammonia,} \\ \qquad\quad \text{or} \\ 33{\cdot}3 \text{ of the oxide,} \end{array}\right.$$

and the per centage of ammonia in the sample is ascertained by the same simple proportion:—As 50 : x :: 100 : y.

Ten thousand tons were about the average manufacture of ammoniacal salts last year—1853—of which about three thousand eight hundred tons were chloride, four thousand five hundred tons sulphate, and about one thousand seven hundred tons were bicarbonate; the former sells at a cost of twenty-five to twenty-eight pounds the ton, the sulphate at seven pounds, and the bicarbonate at thirty to thirty-five pounds per ton, according to its quality.

ANTIMONY.—*Antimoine*, French; *antimon*, German; *stibium*, Latin.—Primarily, a metallic ore consisting of sulphur combined with a metal; the stibium of the Romans. It has been shown at page 48, that the ancients used to designate an antimonial preparation by the appellation *alkohol*. It was used for painting the eyebrows, and Eastern ladies still apply it for that purpose; it no doubt imparts a degree of freshness to the complexion, and adds in many instances to its beauty; it bore a Greek name, signifying large eyes, from the circumstance of its being employed for the embellishment of those organs. Modern science has discovered that the substance known to the ancients was a sulphide of antimony, which is, consequently, the first compound of the metal on record; the word is also used in modern times to denote the pure metal.

The principal ores of antimony are found in the mines of Bohemia and Hungary, in France, England, and in America. During the age of alchemy, various other antimonial compounds were discovered; and an account of the metal is found in the writings of BASIL VALENTINE in 1460.

Antimony is met with abundantly in nature—metallic, combined with other metals; namely, with a little silver and iron in native antimony; with silver in antimonial silver; with arsenic in arsenical antimony; with sulphur and sulphides of other metals—for example, *per se*, in grey antimony, which generally contains copper, arsenic, and iron; with iron in Berthierite; with nickel and arsenic in nickeliferous grey antimony; with lead and traces of iron, copper, bismuth, and zinc in Jamesonite; with lead, copper, and iron in Bournonite; with lead, and a trace of copper, in zinkenite; with lead in antimonial lead glance; with silver and copper in melan glance; with silver, copper, and iron in miargyrite; with silver in dark ruby silver, rhombohedral ruby blende; with silver and arsenic in light ruby silver; and with arsenic, silver, and iron in arsenical silver. It is found, more or less, in the following argentiferous minerals; namely, with silver, copper, iron, and zinc, in weissgiltigerz and graugiltigerz; with copper and silver in antimonial grey copper, tetrahedral copper glance; and in very minute quantity, with copper, iron, silver, and arsenic, in kupfer-blende. It occurs as an oxide in white antimony, which is sometimes contaminated with sesquioxide of iron, and with sulphide of antimony in the red antimonial ore; also as antimonious acid in antimonial ochre.

Antimonial copper—*Antimonkupferglanz*, German—is composed, according to SCHRÖTTER'S analysis, of—

	Centesimally.
Lead,	29·902
Copper,	17·312
Antimony,	16·644
Arsenic,	6·036
Iron,	1·404
Sulphur,	28·702
	100·000

Such results do not conveniently admit of being represented by a chemical formula. If the metals enumerated be calculated as sulphides, thus, $Pb\,S$, $Cu\,S$, $Fe\,S$, $Sb\,S_3$, and $As\,S_3$, the amount of sulphur taken up would be only 25·229, whereas the analysis yields 28·602.

The principal sources of the antimonial ores are the Continental mines, very little of the metal being found in this country. The ore submitted to reduction is the sulphide of antimony—grey antimony—of which from six hundred to a thousand tons are annually imported into England.

In the laboratory, the metal is prepared in a variety of ways: if eight parts of powdered sulphide of antimony be intimately mixed with six parts of tartar—tartrate of potassa—and three of nitre, and the mixture be thrown in small portions into a red-hot crucible, and kept at redness for some time, a metallic button collects at the bottom. The antimony thus obtained is, however, impregnated with small traces of iron, and resembles the better sort of the crude metal found in the market.

When the sulphide of antimony—mixed with some charcoal to prevent the caking of the mass—is heated in contact with air, the greater part of the sulphur is expelled and teroxide of antimony formed; this may now be reduced to metal, either by fusing with an adequate quantity of black flux, or with the addition of ordinary soap; a button of impure metal remains. The purest antimony is procured by reducing either the teroxide with powdered charcoal and alkali, or the potassio-tartrate at a proper degree of heat.

As met with in commerce, antimony is more or less impure, in consequence of some imperfections or mismanagement in the process of its reduction. The contaminations are generally lead, iron, arsenic, and sulphur; but these may be separated by grinding the crude metal in an iron mortar, and fusing the powdered mass with one-tenth of its weight of nitrate of potassa, which oxidizes all the foreign ingredients, as well as a part of the antimony, leaving the remainder in a pure state.

Antimony is very brittle, possesses a white silvery aspect, and a plated crystalline texture, so that, when broken up,. the fracture exhibits beautiful facets. It happens, also, that when the metallic button of antimony is suffered to cool in the crucible, the surface presents a fine stellated appearance. In consequence of this crystalline property, the alchemists considered the phenomenon symbolical of that mysterious luminary which was to guide them in their occult path to the discovery of a universal medicine, or the philosopher's stone.

At 800° Fahr. the metal fuses, and at a white heat it slowly but distinctly volatilizes in closed vessels; in a current of hydrogen, however, it distils with tolerable facility. If exposed to a stream of oxygen, on ignited charcoal, it burns brilliantly, evolving a white light, and is at the same time converted into the teroxide, which is eliminated in the form of a thick whitish smoke. Should a globule of the metal, at a high temperature, be dropped from an eminence upon a board, or plate of iron, the mass subdivides into numerous smaller globules, which hop along the plane in a combustible state, marking the course they take by a white streak or line.

Antimony is not sensibly affected on exposure to the air at the ordinary temperature; its surface becomes slightly tarnished, but does not rust. If exposed to the air during fusion, rapid oxidation takes place.

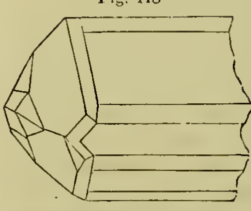
Hydrochloric acid dissolves antimony with the evolution of hydrogen, and the formation of the terchloride; concentrated sulphuric acid oxidizes it, sulphurous acid being at the same time evolved; but if the acid be diluted with water, it does not dissolve it. Nitric acid, even when very dilute, rapidly attacks antimony, and converts it into a white insoluble powder—teroxide of antimony, antimonious or antimonic acid, according to the strength of the acid and the time of digestion.

Aqua regia converts the metal into the terchloride. The specific gravity of antimony is 6·712, and the specific heat, according to REGNAULT, is 0·05077; its atomic or combining weight is 129, and its chemical symbol Sb, derived from the Latin, *stibium.*

For preparing the metal on a large scale, the sulphide is generally employed, as well for the abundant produce which it yields, as from the reduction being more easily effected than that of any other ore of the metal, with the exception of the native oxide; the latter, however, is never met with in sufficient quantity, and, consequently, is seldom used.

There are two varieties of the sulphide of antimony, the massive and the fibrous: the former presents a long columnar composition; and the latter is distinguished by its plumous, woolly, or felt-like appearance; it is of a light lead color, but sometimes dull externally, and often iridescent.

Fig. 118



The mineral is met with in crystals of the rhombic prism—Fig. 118—which are sometimes aggregated laterally. Before the blowpipe, on charcoal, sulphide of antimony fuses, and is absorbed, giving off at the same time sulphurous acid and white fumes of the teroxide of the metal.

The most celebrated localities productive of this mineral are, Felsobanya, Chemnitz, and Cremnitz, in Hungary, whence the grey antimony is procured; Dumfriesshire in Scotland, where the fibrous and laminated variety is found; and Cornwall, where the massive sort is raised. Other varieties of the sulphide are also to be found, as at Magurka, in Hungary; at Freyberg and Braunsdorf, in Saxony; and at Stolberg, in the Hartz. Various analyses of the sulphide have been made, which, of course, differ in their results, according to the greater or less amount of forcign matter present. The appended analyses of the pure mineral, by THOMSON and BERGMANN, show its composition:—

			Centesimally represented.	
	Atomic weight.	Theory.	Thomson.	Bergmann.
1 Eq. of antimony,	129	72·89	73·77	74·0
3 Eq. of sulphur,	48	27·11	26·23	26·0
	177	100·00	100·00	100·0

MANUFACTURE OF ANTIMONY ON THE LARGE SCALE.—Many of the operations in the preparation of antimony on the large scale are the same as those which will be mentioned hereafter, when describing the dry assay of the antimonial compounds. The method most commonly followed is, first to deprive the sulphide of antimony of its sulphur, and substitute oxygen by heat and free access of air, as in the annexed equation:—

$$\underbrace{Sb\,S_3}_{\text{Tersulphide of antimony.}} + \underbrace{O_9}_{\text{Oxygen.}} = \underbrace{Sb\,O_3}_{\text{Teroxide of antimony.}} + \underbrace{3\,S\,O_2}_{\text{Sulphurous acid.}}$$

This change is conducted in a reverberatory furnace, where the comparatively large amount of oxygen required to displace the sulphur, which is also oxidized, is derived from the superabundant current of air flowing over the heated mineral. During the roasting, the attendant should be mindful of the great volatility of the sulphide of antimony, and regulate the heat to prevent the loss of material which would attend the application of a too elevated temperature. The charge of sulphide should be well stirred with an iron slicer or spatula during the roasting, to insure every part coming in contact with the atmosphere. When properly roasted, the mass has a greyish-white appearance.

Having obtained the oxide in the manner described, it is intimately mixed with about a tenth of its weight of crude tartar, and reduced in large earthen crucibles, heated in a wind furnace, when the subjoined decomposition takes place:—

$$\underbrace{Sb\,O_3}_{\text{Teroxide of antimony.}} + \underbrace{K\,O, C_8\,H_4\,O_{10}}_{\text{Tartrate of potassa.}} = \underbrace{Sb}_{\text{Antimony.}} + \underbrace{K\,O, C\,O_2}_{\text{Carbonate of potassa.}} + \underbrace{7\,C\,O}_{\text{Carbonic oxide.}} + \underbrace{4\,HO}_{\text{Water.}}$$

The antimony thus obtained is tolerably pure, and is ready for market. Iron is the principal, and often the only impurity present.

At Linz, in Germany, a furnace, similar to that represented in the annexed cuts, was constructed for the reduction of antimony at one operation. Fig. 119 shows a vertical section; the bed is concave, and is constructed of sand and clay well consolidated; at its middle, a pipe, *a*, forms a canal for the fused metal to flow out as soon as produced, and which is closed by heavy ashes. *b* is the air channel in the bridge *d*, and *c* is a door through which the prepared ore is introduced and the residuary slag abstracted. The fire is shown at *f; e* is the grate, and *g* the chimney.

Fig. 119.

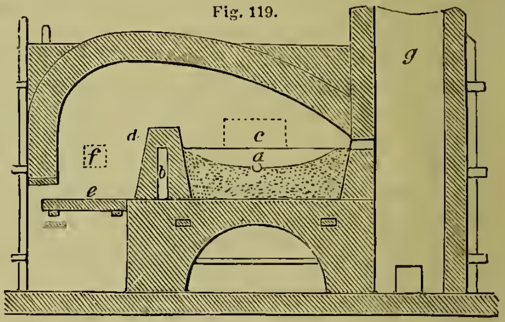


Fig. 120.

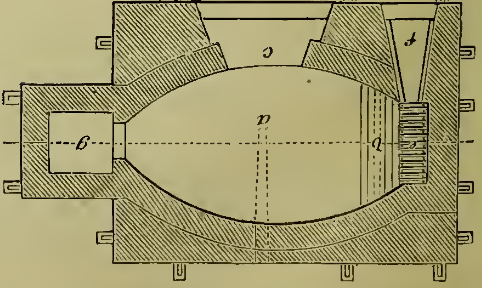


Fig. 120 is a plan of the preceding, wherein the same letters indicate the same parts as previously described.

Sulphide of antimony is dressed for reduction by mixing it with the proper quantity of iron, or iron scales, and alkaline carbonate. Two or three hundred-weight of ore require from eight to ten hours' heat for reduction; but the metal obtained in this way is very impure, and is, therefore, remelted in portions of from twenty to thirty pounds in crucibles, covered over with ground charcoal, and heated in a reverberatory furnace.

The metal obtained by this process contains considerable quantities of iron, sulphur, and frequently arsenic, lead, and copper; and as these bodies deteriorate its quality, even for the arts, and as it cannot be employed in medicine while the smallest trace of arsenic is present, it becomes imperatively necessary to subject the crude article to purification. For this purpose it is fused with one-eighth part of sulphide of antimony, and an equal weight of carbonate of soda, in a hessian crucible, for one hour. On breaking the crucible, after cooling, the metal is carefully separated from the slag and submitted to a second fusion with one part and a half of the carbonate, and sometimes a third fusion may be required; but in this case it is to be performed with one part of the alkaline carbonate. Should there be lead, it remains in the antimony after the second fusion, although the other metals may be completely removed; and from its great fusibility, slight portions are retained even after the third operation.

If arsenic be absent, a part of the metallic antimony is oxidized and remains in the slag; but very little, if any, of the metal is thus acted upon whilst arsenic is present.

It has been found that a hundred parts of the crude metal and six parts of the sulphide yield ninety-four of pure antimony. It is necessary, when larger quantities of iron are present, to add proportionally more of the sulphide of antimony—as eight parts of the impure metal, two of the sulphide, and two of carbonate of soda; for, unless there be sufficient sulphur to combine with the whole of the iron, the arsenic cannot be oxidized.

Wöhler recommends deflagration of ten parts of the metal with twelve of saltpetre and ten of carbonate of soda; the arsenic is oxidized, and forms an arsenite of potassa, and also the antimony converted into antimoniate of potassa by this treatment. On boiling the fused mass with water, the arsenical compound is dissolved, leaving the antimoniate, which is collected, washed, dried, and reduced in the usual way with charcoal in an earthen pot.

The metal obtained by this means still contains copper and iron.

According to **Berzelius**, the impurities are removed by fusing two parts of the metal in fine powder with one part of teroxide of antimony; the iron, copper, and arsenic are oxidized, and remain in the slag; in this case the lead—should any be present—is still combined with the antimony. The Editor suggests that it is better to fuse a little more than four parts of antimony with one part of peroxide of manganese, and to subject the regulus so obtained to a second fusion with one-tenth of its weight of carbonate of soda.

As the sulphide of antimony is nearly always associated with seams of silicious and calcareous impurities, a preliminary operation is resorted to in order to separate them; this process is called *eliquation.*

Any difference that exists in the manner of eliquating crude sulphide of antimony is chiefly in the furnace employed. In Hungary, the ancient method of introducing the ore into large pots or crucibles is still practised. These pots are furnished with an aperture at their bottom, opening into a smaller one, which is embedded in the ground. A cover is appended to the upper pot, which may be luted down after the vessel is charged. These pots are placed in a circle with a furnace in the centre, the heat from which passes freely under the bottom and round the body of each pot.

Figs. 121 and 122 are drawings of this arrangement; the former is a section of the elevation, and the latter a plan, showing the position of the crucibles round the fire. *a a a* denote the pots wherein the crude ore is heated, and *c c c* the smaller pots which receive the liquid sulphide; *d* is the fire-grate. In the elevated section, the relative position of these crucibles is comprehensively shown, with their connecting tubes, *b b;* both crucibles and tubes are made of earthenware.

Fig. 121.

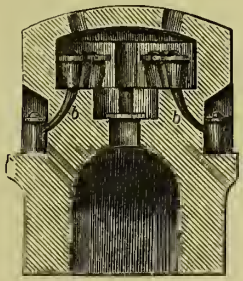
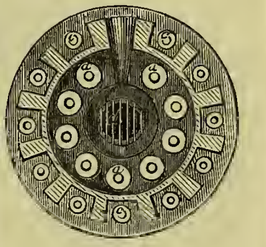
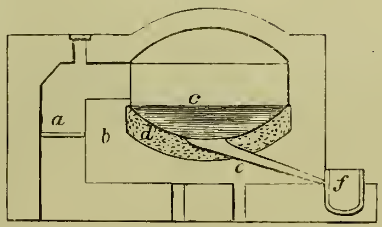


Fig. 122.



The furnace employed for the eliquation of the crude sulphide, at Vandée, in France, is represented in Fig. 123, where, instead of several pots being situated around the fire, the bed of the reverberatory, which is connected with a recipient for the purified material, supplies their place. In the figure, *a* represents the fire-place, *b* the bridge of the furnace, *c* the concave hearth, lying on the substrata, *d; e* is the pipe which issues from the bottom of the furnace hearth, and carries the liquid products along to the recipient, *f.* The furnace is heated by the flue passing around the body, and the charge is introduced through an opening in the dome, not shown in the woodcut. Such a con-

Fig. 123.



struction of furnace is preferable to the preceding, both from the simplicity of its arrangement and the advantage of its being reverberatory. When moderately rich ores are subjected to purification, the charge, which is usually from eight to ten hundredweight, yields from four to five hundredweight of the purified substance, with a consumption of about twenty-five cubic feet of wood as fuel. Three such charges may be worked off in the long days of summer.

The best furnace for the separation of the sulphide of antimony from its matrix, is that in use at the extensive mines of Malbose, in the Ardèche Department in France, and is sketched in the subjoined engravings. Fig. 124 is a vertical view of the plan on a line with the flues which issue from the several fires, and which are denoted by the letters *f g h*, and the grates, whereon the ignited fuel is supported, by *a b c*. These grates are four feet and a half in length by about a foot in breadth, and are separated by two square galleries, *d* and *e*, running parallel through the furnace, and protected from the direct action of the fire by walls, having the alternate openings, *f g h*, serving as flues, to conduct the heat into the galleries, which are closed by the iron doors, *i i*, at each end.

Fig. 125, the elevated section of this plan, explains the nature of the arrangement.

In this drawing all the parts before referred to are indicated by the same letters. The galleries, *d d*, hold two large crucibles, *k k*, of cast-iron; and, in order that they may not adhere to the sulphide of antimony which flows into them, they are covered with clay luting. To each of these crucibles a set of wheels, running on parallel bars of iron, leading into the furnace, is affixed. In this way the crucibles are charged, fixed in the furnace, and withdrawn with facility. Both galleries are covered with flat tiles of firebrick, *l l*, on which the conical fire-clay cylinders, *m m*, rest. Sulphide of antimony for eliquation is introduced into these fire-proof cylinders, and the product, purified by fusion, is received in the lined crucible beneath the cover, *l l*, through the connection, or small opening, *n*, at the base of the cylinders. *q q* is the arch of the furnace through which the cylinders ascend, by openings somewhat larger than their outer diameters; these orifices are closed at the top by clay covers, *r r*. The arch at the top, *s*, is constructed cylindrically, forming a double cross arch.

Fig. 124.

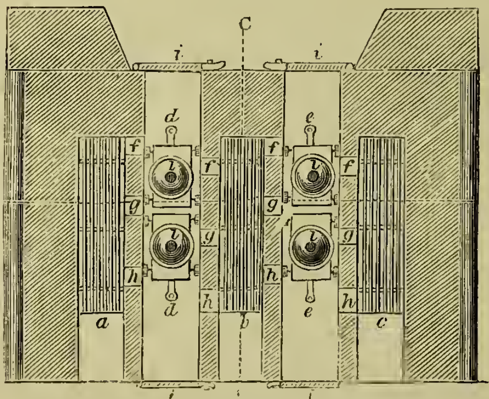
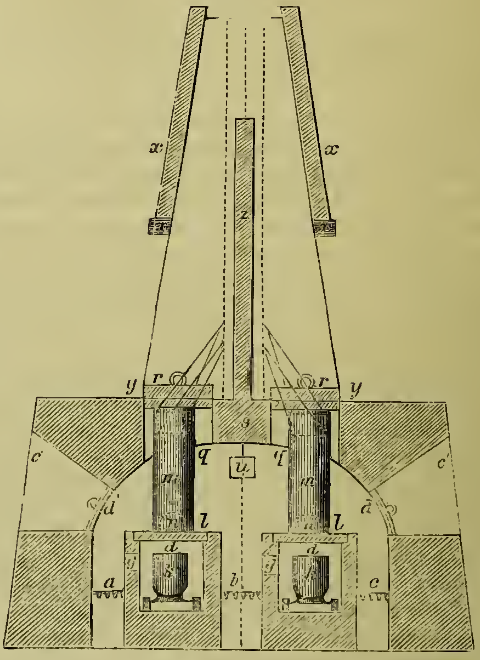
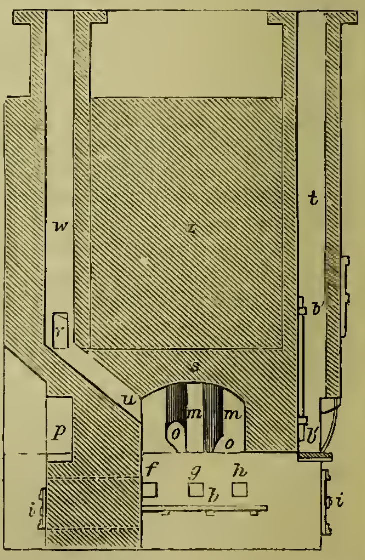


Fig. 125.



After the flame from the fire has played round the cylinders containing the mineral, it departs through three openings and flues into the chimney, *t*—Fig. 126. Two of these openings are indicated by the letters *u* and *v*, in this figure, which is a section of the elevation following the line, C D, of Fig. 124; these flues are provided with valves. *w* is a chimney for carrying off antimonial vapors which may be expelled from the cylinders while drawing out the slag and exhausted ore. Another chimney, *x*, begins above *y y*—see Fig. 125—where the cylinders are charged; a partition, *z*, divides this chimney into two parts, so that the workman, while operating on one side, is not inconvenienced by the fumes of the other. *o o* are orifices several inches in height, by which the cylinders may be reached from the front and back part of the furnace by conical

Fig. 126.



openings, such as *p*, in the walls; the openings, *o o*, are closed during the working with clay stoppers, *n n*, seen in the preceding figure, which are removed at the end of an operation. *a′* and *b′ b′* are iron and wooden beams and bands to brace the chimneys. *c′ c′* are conical arches on both sides of the furnace, closed with well-fitting plates, *d′ d′;* through these the interior of the furnace may be examined, and repairs made, when required.

Each cylinder is charged with four hundred and ninety pounds of ore, previously warmed on the arch, the coarsest and richest of which is placed at the bottom of the cylinders. As soon as the eliquation is completed, the impurities remaining are withdrawn through the openings, *o o*, and a fresh charge introduced. The sulphide of antimony produced should have a bluish color; if it possesses a reddish appearance, it is indicative of too great a heat. When the iron recipients are three quarters filled, they are drawn out and allowed to cool, and the lump of crude antimony—sulphide—removed. Fresh charges are put in every three hours, and about one hundred pounds of the sulphide obtained at each process, when the furnace is in successful operation. On an average, the cylinders last about twenty days.—*Booth.*

The product from the preceding operations is roasted in a reverberatory furnace to expel the whole of its sulphur, and produce instead the teroxide of the metal; the latter is subsequently reduced by mixing it with about twenty per cent. of charcoal, saturated with a strong solution of carbonate of soda. According to Berthier, seventy per cent. of good metal may be procured from the ordinary product of eliquation of the crude sulphide, as above, when mixed with sixty parts of iron scales from the hammer or rolling mill, forty-five to fifty of carbonate of lime, and ten to twelve of powdered charcoal, and the mixture heated to fusion in the ordinary way. Iron is often found in considerable quantities in the antimony procured from this mixture; and, therefore, unless subsequently purified, it cannot, in many instances, be advantageously employed.

Uses in the Arts.—Antimony is chiefly used as an ingredient in the construction of alloys, such as type-metal, Britannia-metal, plate-pewter, and various others. The typefounder uses two alloys of antimony, lead, and tin; the one composed of—

Tea lead,....	75		Tea lead,.....	70
Antimony,..	20	and the other	Antimony,....	25
Block tin,...	5		Block tin,.....	5
	100			100

Stereotype metal is formed of

Tea lead,.........................	112 lb.
Antimony,.........................	18 "
Block tin,.........................	3 "
	133

The best Britannia-metal in one of the largest manufactories in Birmingham is composed as follows:—

	Centesimally.
Tin,....................................	90
Antimony,..............................	10
	100

A higher proportion of antimony is sometimes used. From three to six per cent. of copper was formerly added; but this metal is now discarded, or is only used to give color, in the proportion of about one and a half per cent. for good metal. The best Britannia-metal is nearly all tin, with no addition but antimony, as above stated. Lead, which is given in some recipés, is carefully avoided. Bismuth is also rejected in good articles. Nearly every manufacturer, however, uses different proportions, according to the quality of his tin, a small quantity of which he previously tries with antimony, to find out the best result with that particular quality of tin upon which he is about to operate.

The specific gravity of the first three alloys above mentioned is greater than the calculated mean of the metals, on account of a contraction of volume taking place at the moment of cooling. With those alloys where tin is in excess, the result is opposite, for at the point of solidifying the mixture expands, and, consequently, the gravity is reduced.

Antimony is used as an ingredient in the preparation of concave mirrors for giving a finer texture to the mass, on which account it takes a better polish; and in the casting of bells, for the purpose of giving a clearer and stronger sound, as also to make them harder and whiter than they would otherwise be. From its easy fusibility, it is used to promote this property in other metals which may be employed for artistic or manufacturing purposes, especially in casting cannon balls.

The negative elements with which antimony forms the principal compounds are, oxygen, sulphur, and chlorine, which unite with it in various proportions, as seen in the annexed table:—

Name.	Symbol.		Atomic weight.
Teroxide of antimony,....	$Sb\ O_3$	....	153·0
Antimonious acid,.........	$Sb\ O_4$	....	161·0
Antimonic acid,...........	$Sb\ O_5$	....	169·0
Tersulphide of antimony,..	$Sb\ S_3$	....	177 0
Quadrasulphide,..........	$Sb\ S_4$	....	193·0
Pentasulphide,............	$Sb\ S_5$	....	209·0
Oxysulphide,..............	$Sb\ S_3$, $Sb\ O_3$	....	330·0
Terchloride of antimony,..	$Sb\ Cl_3$	....	235·5
Quadrachloride of antimony,	$Sb\ Cl_4$	....	271·0
Pentachloride of antimony,	$Sb\ Cl_5$	....	306·5

It also unites with bromine, iodine, and selenium.

Of the preceding compounds, the tersulphide, terchloride, and teroxide, are the only important bodies in a manufacturing point of view; and are, with the exception of the tersulphide which is employed to prepare the metal, almost exclusively used in medicine. These will now be described.

Tersulphide of Antimony.—*Crude antimony—antimony ore—sesquisulphide of antimony; schwefelspiessglanz—anderthalb—schwefelspiessglanz rohes antimon,* German; *stibium sulphuratum nigrum, lupus metallorum,* Latin.

Having already described the principal use of this antimonial compound, and the method followed for purifying it, nothing further remains but to add a few words on the manner in which the pure sulphide is procured for other purposes. That noticed in the foregoing, even after careful eliquation, contains variable quantities of sulphides of iron, lead, copper, and arsenic; hence the black streak which the eliquated compound makes, instead of a blackish red, which is formed by the pure substance. It may be prepared in the dry way, by fusing thirteen parts of pure antimony and five of flowers of sulphur—sublimed sulphur—in a crucible, the mixture being introduced by degrees and at short intervals. After the whole has been fused, the crucible is taken from the fire and inverted, to allow the melted sulphide to flow out. The whole of the metal may not be decomposed in this operation, but those portions which have escaped the action of the sulphur are easily removed.

In the humid state, sulphide of antimony may be manufactured in various ways: firstly, by conducting a stream of sulphide of hydrogen gas through a concentrated solution of tartar emetic—bitartrate of antimony and potassa—an orange red precipitate is formed, which is the sulphide in question; secondly, when *kermes mineral* is digested in the heat with tartaric acid, any oxide of antimony, as well as potassa, which may be present, is removed, and the pure tersulphide of antimony remains; and thirdly, by digesting a mixture of one part of crude sulphide of antimony with one part of pearl ash—crude carbonate of potassa—one and a half of slaked lime, and fifteen of water, in a closed vessel for two hours. During the digestion, a soluble double sulphide of antimony and alkali is formed; and on adding sulphuric acid to decompose the alkaline sulphide, sulphide of antimony falls down; this precipitate is then filtered, washed with sulphide of hydrogen water, and dried.

Pure sulphide of antimony, as prepared by the first method, has a steel-grey color, a shining metallic lustre, and a fibrous crystalline texture; it is brittle, and gives a reddish-black streak upon paper; it is very fusible, but less so than the metal, boils at a high temperature, and partially distils in a current of gas. When heated to whiteness in a crucible, it loses from ten to twelve per cent. of its weight of sulphur; heated in the air, it suffers decomposition, giving off its sulphur in the form of sulphurous acid, and absorbing oxygen, which converts it into teroxide of antimony.

A current of hydrogen gas passed over it at a low red heat completely desulphurizes it, leaving pure metal. This property of hydrogen—that of depriving it of sulphur at a red heat—is possessed also by many metals, of which the most energetic is iron. When exposed with charcoal to a white heat, the sulphide of antimony is reduced to metal.

When the sulphide and teroxide of antimony are fused together, combination takes place, without either of the compounds suffering decomposition.

The following analyses by BERZELIUS and THOMSON show the composition of pure sulphide of antimony:—

		Centesimally represented.		
	At. weight.	Theory.	Berzelius.	Thomson.
1 Eq. of antimony,..........	126 ..	72·7 ..	72·8 ..	73·7
3 Eq. of sulphur,............	48 ..	27·3 ..	27·2 ..	26·3
1 Eq. of sulphide of antimony,	174	100·0	100·0	100·0

Its chief use, besides its employment as a source for the production of the metal, is for pharmaceutical preparations, chiefly tartar emetic.

Kermes mineral is another sulphide of antimony, united to an alkaline sulphide, and one which has long been known. For a considerable time it was supposed to consist of oxide of antimony united to the sulphides of the metal, until the researches of BERZELIUS and ROSÉ proved it to be a true sulphide of antimony united to an alkaline sulphide. It may be prepared in various ways:—

Firstly, by heating slowly one part of pure carbonate of potassa and two and three-fourth parts of pure sulphide of antimony, in a covered crucible, till the mass fuses, but does not boil; this mixture is to be boiled with water, and filtered; the compound sulphide dissolves out, and, on exposing the solution to the air, precipitates. After the first filtration, the residue is heated with water, or with the clear mother liquid left after a previous deposit of kermes; a further quantity of the compound is dissolved out, which separates from the liquid, as before, as soon as the whole becomes cold. When the boiling solution has been thus treated three or four times in succession, there remains an insoluble substance, composed of a tersulphide and teroxide of antimony, $Sb\,S_3$, $Sb\,O_3$.

A second method is by fusing two parts of metallic antimony, one of sulphur, and three of carbonate of soda; or sixteen parts of the metal, three of sulphur, and thirty-two parts of carbonate of potassa; it may also be prepared by heating a mixture of from three to four parts of cream of tartar—bitartrate of potassa—and one part of sulphide of antimony, in a crucible, till the vapor of decomposed tartaric acid disappears.

The theory of the formation of kermes will be understood from the behavior of the crude antimony with alkalies or their carbonates.

It has been found that no teroxide of antimony is produced by boiling the ordinary sulphide with a dilute solution of alkaline carbonate; and the appended analysis by ROSÉ proves its absence, even when more alkali is present than the tersulphide could saturate. He found the kermes formed under these circumstances to consist of—

	Centesimally.
Antimony,..........	69·00
Potassium,..............................	2·25
Sulphur,................................	28·41
Loss,...................................	·34
	100·00

From this analysis, it appears that sulphur is present in the ratio of the formula $K\,S_3$, $Sb\,S_3$; he states, however, that no tersulphide of potassium existed, but a sulphantimoniate of sulphide of potassium, $K\,S$, $Sb\,S_5$, which did not appear to be united with the sulphide of antimony. The kermes, which separates after boiling the crude antimony with alkaline carbonate in excess and cooling the liquid, contains teroxide of antimony; the first portions less, the last more of the oxide. After drying the precipitate the teroxide of antimony becomes more apparent, especially if examined with the microscope, which shows its definite crystalline structure, interspersed with the amorphous flocculi of the kermes. Dilute alkaline solutions hold the teroxide of antimony in solution; stronger lies dissolve a larger quantity of this body, but part with it again as the menstrua cool.

During the action of the alkali, a portion of the sulphur united to antimony is exchanged for the oxygen of the alkali, and a corresponding alkaline sulphide with teroxide of antimony is constituted; hence the hot solutions of the alkali, acting upon the sulphide, always give rise to the hyposulphantimonide of the sulphide of potassium, and hypoantimonide of the oxide of potassium.

The same interchange takes place when sulphide of antimony is fused with the alkaline carbonate in the crucible; a portion of the sulphide is, however, reduced to metal, and the sulphur, which it hitherto held in combination, is transferred to the undecomposed sulphide, which is thereby converted to the state of quinquisulphide. Kermes, formed by boiling the sulphide of antimony with potassa, does not contain, according to **BOOTH**, a trace of the oxide of antimony; but **BRANDE** states, on the authority of **BERZELIUS**, that when the mixture is boiled an alkaline sulphide is formed; and the antimony is converted into teroxide proportionately to the oxygen of the decomposed alkali:—

$$\underbrace{3\,K\,O}_{\text{Potassa.}} + \underbrace{Sb\,S_3}_{\substack{\text{Tersulphide}\\\text{of antimony.}}} = \underbrace{3\,K\,S}_{\substack{\text{Sulphide of}\\\text{potassium.}}} + \underbrace{Sb\,O_3}_{\substack{\text{Teroxide of}\\\text{antimony.}}}$$

The sulphide of potassium unites with undecomposed sulphide of antimony, giving rise to a double sulphide of both these metals, $K\,S,\ Sb\,S_3$; and the teroxide of antimony combines with the remaining undecomposed potassa, so that when hot water is added, a solution is obtained, containing the double sulphide of antimony and potassium, and also the oxygen compound of both these metals. As the liquid cools, sulphide of antimony deposits—merely because the solvent power of the sulphide of potassium diminishes by cooling—and carries down with it variable quantities of antimoniated potassa, apparently in combination, as it cannot be removed by washing.

The cold liquor still retains some of the compound sulphide of potassium and antimony, and also the antimoniate of potassa; by adding a dilute acid to this liquid, the sulphide of potassium and water suffer decomposition, being transformed into sulphide of hydrogen and potassa; the antimoniated potassa is likewise broken up, a salt of the alkali with the decomposing acid being formed, by which the sulphide of hydrogen and teroxide of antimony are induced to unite and form a sulphide of that metal which precipitates; this precipitate has a golden yellow color, and is hence called *the golden sulphide of antimony.* It differs from kermes inasmuch as there is no potassium, but more of the teroxide of antimony; and probably it contains an oxysulphide of the metal. The constituents of these two remarkable compounds are contrasted to show their composition, the relative proportions of their components being, however, indefinite:—

Kermes.	Golden sulphide.
Sulphide of antimony.	Sulphide of antimony.
Antimoniated potassa.	Teroxide of antimony.

Kermes mineral, as a medicinal agent, was at one time in high repute on the Continent, where it is still occasionally used in considerable quantities; in England it is scarcely ever prescribed to alleviate human ailments, though used largely as a veterinary medicine. **PEREIRA** states that, when administered in small doses, it acts as a sudorific and liquefacient; in large doses, as an emetic and purgative. It has also been found to act with great benefit as a contra-stimulant, or hyposthenic, in inflammatory diseases, especially in pneumonia. The uncertainty of its operation is, however, a great drawback; even when moderate action follows its use, it is doubtful whether it has any advantage over tartar emetic.

Hydrochloric acid decomposes kermes mineral with the formation of terchloride of antimony, the elimination of sulphide of hydrogen, and the precipitation of sulphur:—

$$\underbrace{K\,S,\ Sb\,S_5,\ Sb\,S_3}_{\text{Kermes.}} + \underbrace{7\,H\,Cl}_{\substack{\text{Hydrochloric}\\\text{acid.}}} = \underbrace{K\ Cl}_{\substack{\text{Chloride of}\\\text{potassium.}}} + \underbrace{2\,Sb\,Cl_3}_{\substack{\text{Terchloride of}\\\text{antimony.}}}$$
$$+ \underbrace{7\,H\,S}_{\substack{\text{Sulphide of}\\\text{hydrogen.}}} + \underbrace{S_2}_{\text{Sulphur.}}$$

Golden sulphide of antimony is completely soluble in hydrochloric acid, with the evolution of sulphide of hydrogen; this behavior shows at once that it is a sulphide, while, like all the other sulphides similarly treated, a solution of terchloride of antimony is formed. When boiled with a solution of bitartrate of potassa, tartar emetic is produced in the liquid, from the solution of the oxide of antimony contained in the precipitate. Its color partly distinguishes it from those sulphur compounds already mentioned. According to **PHILIPS'** analysis, its composition is as follows:—

	At. weight.	Centesimally represented.	
		Theory.	Philips.
1 Eq. of teroxide of antimony,....	153	13	12·0
5 Eq. of tersulphide of antimony,..	885	75	76·5
16 Eq. of water,...................	144	12	11·5
1 Eq. of golden sulphide,........	1182	100	100·0

Bitartrate of potassa extracts, according to the preceding, about twelve per cent. of its weight, being the amount of teroxide of antimony present in the sample.

The commercial article is often of a much brighter color than that just described; it is prepared by boiling the sulphide with potassa and ground sulphur, and, after filtering off the liquor, precipitating the compound by means of an acid in the usual way. **REDWOOD** mentions two methods whereby the product is obtained of a similar color to the commercial article: namely, four parts of the black sulphide of antimony are boiled with eight of lime and eighty parts of water, the liquor strained and precipitated by hydrochloric acid in the usual way; or, two parts of the sulphide may be fused in a crucible with four parts of carbonate of potassa and one of sulphur; the residue, when cold, boiled with twenty parts of hot water; the solution filtered and decomposed by a large excess of sulphuric acid.

The medicinal effects of this compound are more active than those of the kermes, on account of the larger proportion of teroxide of antimony which it contains. Its uses are as an alterative in chronic diseases, particularly cutaneous affections, glandular enlargements, rheumatism, and liver complaints.

Oxysulphide of antimony is another of those compounds, prepared almost in the same way as kermes mineral, with the addition of sulphuric acid to the solution obtained after boiling the sulphide of antimony in the alkaline liquid; the action of the alkali being productive of a hyposulphantimonide of the alkali metal, and likewise a compound of the alkali and oxide of antimony, which are dissolved in the liquid, and also a portion of tersulphide. These are reacted upon as under:—

$$\underbrace{3\,(KS,\,SbS_3)}_{\text{Hyposulphantimonide.}} + \underbrace{KO}_{\text{Potassa.}} + \underbrace{SbO_3}_{\text{Teroxide of antimony.}} + \underbrace{4\,HO,\,SO_3}_{\text{Sulphuric acid.}} =$$

$$\underbrace{4\,(KO,\,SO_3)}_{\text{Sulphate of potassa.}} + \underbrace{3\,SbS_3,\,SbO_3}_{\text{Golden sulphide.}}\ \underbrace{HO + 3\,HS.}_{\text{Sulphide of hydrogen.}}$$

In the preceding decomposition, the whole of the sulphide of potassium and potassa which retain the teroxide and tersulphide of antimony in solution, are converted into a neutral sulphate, with the elimination of sulphide of hydrogen, and the teroxide and tersulphide in conjunction fall down.

Should the liquor, before the addition of the sulphuric acid, contain a pentasulphide of the metal, arising from the absorption of oxygen from the air, it will be precipitated in that state by acids, and hence the composition of the golden sulphide is often variable.

TEROXIDE OF ANTIMONY.—This compound was known to BASIL VALENTINE, who called it *flores antimonii.* In commerce it bears the several appellations of *protoxide, sesquioxide,* and *flowers of antimony.* It may be prepared in several ways—first, by heating metallic antimony to the point of its combustion; it burns with a bluish light, and if the crucible be reclined on one side, to admit a current of air, small acicular crystals of teroxide will be observed on the upper part; secondly,—by adding metallic antimony in powder to sulphuric acid, evaporating the liquid to dryness, and then washing the dry mass, first with water, and next with a weak solution of carbonate of soda, for the purpose of removing the last portions of sulphuric acid; after completely washing the residue, a white powder remains, which is teroxide of antimony; thirdly,—by digesting finely-ground sulphide of antimony in about four times its weight of hydrochloric acid, terchloride of antimony is formed and sulphide of hydrogen escapes with effervescence, the former of which is decomposed by carbonate of soda into teroxide of antimony, which precipitates, while carbonic acid is liberated, and the soda is converted into chloride of sodium by the chlorine of the antimonial compound.

Subjoined is the symbolical arrangement of these decompositions:—

$$\underbrace{SbS_3}_{\substack{\text{Tersulphide of}\\\text{antimony}}} + \underbrace{3\,HCl}_{\substack{\text{Hydrochloric}\\\text{acid.}}} = \underbrace{SbCl_3}_{\substack{\text{Terchloride of}\\\text{antimony.}}} + \underbrace{3\,HS}_{\substack{\text{Sulphide of}\\\text{hydrogen}}}$$

$$\underbrace{SbCl_3}_{\substack{\text{Terchloride of}\\\text{antimony.}}} + \underbrace{3\,NaO,\,CO_2}_{\substack{\text{Carbonate of}\\\text{soda.}}} = \underbrace{SbO_3}_{\substack{\text{Teroxide of}\\\text{antimony.}}} + \underbrace{3\,NaCl}_{\substack{\text{Chloride of}\\\text{sodium.}}} + \underbrace{3\,CO_2}_{\substack{\text{Carbonic}\\\text{acid.}}}$$

The precipitated teroxide is collected upon a filter, washed well with water, and dried. For pharmaceutical purposes, the Dublin college recommends the treatment of twenty parts of the powdered sulphide of antimony with one hundred parts of hydrochloric acid and one of nitric acid; the acid and powder must be slowly brought together, and a gentle heat applied for some time, which may be afterwards increased, and the solution left to digest as long as any effervescence or escape of sulphide of hydrogen is observed; and then the whole is to be boiled for an hour, the liquor filtered when cold, and the filtrate received in a vessel containing one gallon of cold water, which precipitates the basic terchloride of antimony—

$$\underbrace{6\,SbCl_3}_{\substack{\text{Terchloride of}\\\text{antimony.}}} + \underbrace{15\,HO}_{\text{Water.}} = \underbrace{(SbCl_3,\,5\,SbO_3)}_{\substack{\text{Oxychloride of}\\\text{antimony.}}} + \underbrace{15\,HCl}_{\substack{\text{Hydrochloric}\\\text{acid.}}}$$

The oxychloride is collected, and washed with water till the washings cease to evince an acid reaction with litmus paper. During the washing of the precipitate the following change occurs:—

$$\underbrace{(SbCl_3,\,5\,SbO_3)}_{\substack{\text{Oxychloride of}\\\text{antimony.}}} + \underbrace{3\,HO}_{\text{Water.}} = \underbrace{6\,SbO_3}_{\substack{\text{Teroxide of}\\\text{antimony.}}} + \underbrace{3\,HCl}_{\substack{\text{Hydrochloric}\\\text{acid.}}}$$

showing that the water is decomposed, its oxygen being retained by the antimony, which yields the chlorine combined with it to the hydrogen, forming hydrochloric acid.

DUMAS directs the preparation of teroxide of antimony to be conducted as follows:—Heat pulverized antimony in a shallow vessel exposed to the air; when the oxidation has advanced, the metal takes fire and becomes incandescent, antimonious acid—mixed, however, with some of the metal—being produced; the whole of the compound is now transferred to a crucible, in which it is heated to fusion, when the antimonious acid is reduced to the state of teroxide by the excess of metal, which is found, with the fused mass, in a button at the bottom.

Teroxide of antimony is a white powder, fusible, and volatile at a red heat; when heated in close vessels it suffers no change, but is partly sublimed, and condenses in acicular crystals on the cover, or upper part of the pot. Sometimes, however, the crystals are found in octahedrons.

If the teroxide be kept in fusion, with contact of air, it is converted into a higher state of oxidation; but if the air be excluded, it concretes into a silky crystalline mass, presenting a greyish appearance.

Water dissolves traces of teroxide of antimony, as proved by the solution assuming a yellow color when treated with sulphide of hydrogen. If heat be applied to this liquid, and a slight addition of hydrochloric acid be made, the orange-red sulphide of antimony falls down. Nitric acid and chlorate of potassa rapidly convert the teroxide into a higher degree of oxidation; sulphur decomposes it in the heat into a sulphide, with the formation of water; and when heated to redness with charcoal, metallic antimony is obtained. Tartaric acid readily dissolves the oxide; bitartrate of potassa acts similarly, producing in either case tartar emetic. On boiling recently precipitated teroxide of antimony with a concentrated solution of potassa, a compound body of both oxides is formed, which falls down in the form of a greyish powder, or white crystalline grains, difficultly soluble. With soda and ammonia similar bodies are produced.

Teroxide of antimony is composed of

		Centesimally.	
	Atomic weight.	Theory.	Berzelius.
1 Eq. of antimony,....	129	84·316	84·319
3 Eq. of oxygen,.....	24	15·684	15·681
1 Eq. of teroxide,.....	153	100·000	100·000

TERCHLORIDE OF ANTIMONY—BUTTER OF ANTIMONY—is used to some extent in medicine, chiefly as a caustic, and as such takes its place among the antimonial preparations. It is the principal ingredient in some patent medicines lately offered to the public, which are said to be next in efficacy to the *elixir vitæ*. It will be necessary, therefore, to give here a short description of its preparation and properties.

On dissolving sulphide of antimony in hydrochloric acid, as before explained, terchloride of antimony is formed, with the evolution of sulphide of hydrogen. The action of the hydrochloric is greatly accelerated by mixing with it a small proportion of nitric acid. When the solution thus obtained is evaporated, the butter of antimony remains in the solid state. To prepare the pure salt, BERZELIUS recommends that the hydrochloric acid solution of the terchloride should be evaporated in a porcelain dish, till it begins to crystallize on the dish being placed in a cold situation; the concentrated liquid is then transferred to a retort, and distilled until a drop of the liquid solidifies upon a cold surface; at this point the receiver is changed, and the remaining portion of the charge collected as pure.

It is white, semitransparent, crystalline, of a buttery consistence, and deliquescent in the air; heated to about 162° Fahr. it flows like oil, and boils at 446°.

When added to water it gives a bulky white precipitate of oxychloride of antimony—$Sb\,Cl_3 + 5\,Sb\,O_3$—while the supernatant liquor is charged with hydrochloric acid: tartaric acid dissolves the oxychloride; hence, if that acid be present previous to the addition of water, no precipitate is produced.

Terchloride of antimony affords, with all the other reagents, similar reactions to those which distinguish the other salts of this metal.

Its composition is—

		Centesimally.	
	Atomic weight.	Theory.	Rosé.
1 Eq. of antimony,............	129 ..	54·83 ..	53·27
3 Eq. of chlorine,............	106·5 ..	45·17 ..	46·73
1 Eq. of terchloride of antimony,	235·5	100·00	100·00

Besides being used as a caustic, it is employed in the arts, especially by gunmakers, for the purpose of giving a yellow color to gun barrels, and is called *bronzing salt*. It is used for this purpose in the state of solution, mixed with olive oil, and rubbed over the iron slightly heated, which is then exposed to the air till the desired color is obtained. Sometimes, to quicken the effect, nitric acid is added. When bronzed, the surface of the iron is polished by a burnisher, or by wax, or by varnish composed of two ounces of shell-lac and three drachms of dragon's-blood dissolved in two quarts of spirit of wine. The bronze color is due to sesquioxide of iron, and hence other metals often containing copper are employed.

QUANTITATIVE ESTIMATION OF ANTIMONY BY ANALYSIS.—As those engaged in docimacy should be able to judge of the quality and nature of all substances appertaining to metallurgy, at least of those compounds with which they are immediately engaged, the mode of analysis and assay of the metals and their principal ores, will be given as they come under consideration.

The per centage of antimony in a mineral may be estimated from the amount of the *sulphide of antimony*, the *antimonious acid*, or of the *pure metal*, which it produces when operated upon with appropriate reagents. A solution of the metal is obtained by treating the ore with strong hydrochloric acid, containing some nitric acid—in case of the absence of silver—and diluted with water; should any turbidness ensue, tartaric acid must be added to dissolve it, or, if the addition of this acid would interfere with the estimation of any other metal, hydrochloric acid is employed to effect the same purpose. Sulphide of hydrogen is next transmitted through the liquid, until the solution acquires the strong odor of the gas; if antimony is the only metal present, the beaker or flask holding the precipitate may be placed on a hot sand-bath till the excess of sulphide of hydrogen is expelled.

By this means the small quantity of sulphide of antimony retained in solution by the excess of the gas is set at liberty. The menstruum is then filtered through a dried and tared filter, washed with water, desiccated at 212° till the weight remains constant, then weighed. As the antimony in solution is often in a higher state of oxidation than the teroxide, especially if nitric acid has been employed, and as more or less of the sulphide of hydrogen is decomposed by the free acid of the solution before precipitation, the sulphide of antimony produced contains an excess of sulphur, so that from its weight the true quantity of metal cannot be deduced. In this case the dry compound is detached as much as possible from the filter, and the latter reweighed with any adhering portions; the difference of weight equals the quantity of sulphide taken. This sulphide is introduced into a flask, and strong nitric acid, in successive small portions, added to prevent any loss of the substance by the too energetic operation of the acid. After the action has ceased, hydrochloric acid is added to dissolve the whole of the antimonious acid, formed by the action of the nitric acid upon it.

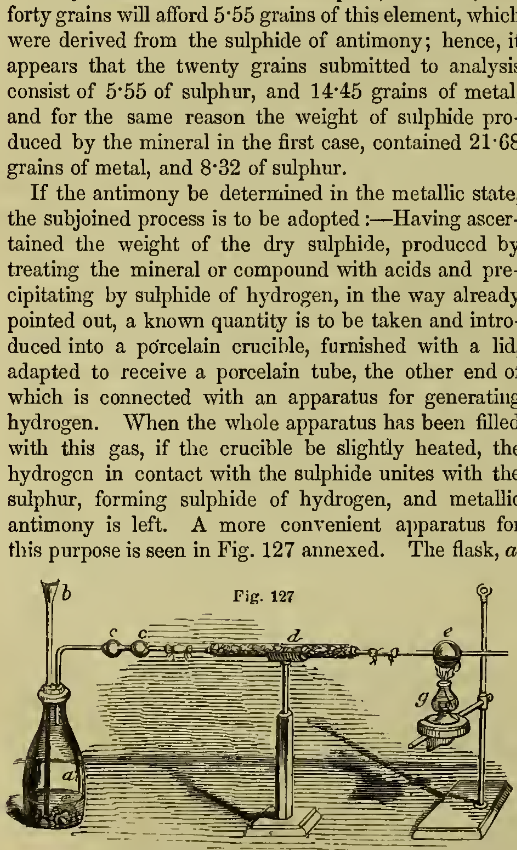
If dilute nitric acid had been taken in the first instance, there would be a certain quantity of sulphide of hydrogen formed, and which, by its escape, would cause an error in the result. After the whole of the sulphide has been oxidized into sulphuric acid and antimonious acid, and any portions of the latter which might have precipitated, redissolved by tartaric or hydrochloric acid, a solution of chloride of barium in excess is poured into the liquid; this occasions a deposit of sulphate of baryta, which, after being filtered, is dried, ignited, and weighed. From the amount of sulphate of baryta, that of the sulphur in the sulphide of antimony operated upon is calculated, and by deducting this from the weight of the sulphide of antimony, the weight of the metal is indirectly obtained.

In case too much tartaric acid had been used, before precipitating the sulphuric acid by the chloride of barium, some tartrate of baryta is likewise thrown down, and cannot be removed by washing. To ascertain, therefore, the real weight of the sulphate of baryta, the precipitate of mixed sulphate and tartrate, after being heated to redness and weighed, is treated in the crucible, or a small beaker, with a few drops of strong nitric acid, heated, and filtered, the residue washed well with hot water, dried, and reweighed. If the weight of sulphate, as now ascertained, corresponds with that which was previously found, no tartrate of baryta was present, but, should a difference be found, it arises from the tartrate of baryta which was deposited in conjunction with the sulphate, but which was decomposed during the ignition, leaving carbonate of baryta, a salt easily soluble in hydrochloric or nitric acid. The latter weighing gives the true amount of sulphate of baryta.

That the calculation of the analysis may be better understood, the following is an example:—If the weight of ore taken furnished a precipitate of mixed sulphides of antimony weighing thirty grains, twenty of which, when treated with nitric acid in the manner already described, yielded, on being precipitated with chloride of barium, a quantity of pure sulphate of baryta, the weight of which may be supposed to be forty grains—since, in round numbers, one hundred and seventeen grains of the baryta salt contain sixteen of sulphur, it follows, that forty grains will afford 5·55 grains of this element, which were derived from the sulphide of antimony; hence, it appears that the twenty grains submitted to analysis consist of 5·55 of sulphur, and 14·45 grains of metal, and for the same reason the weight of sulphide produced by the mineral in the first case, contained 21·68 grains of metal, and 8·32 of sulphur.

If the antimony be determined in the metallic state, the subjoined process is to be adopted:—Having ascertained the weight of the dry sulphide, produced by treating the mineral or compound with acids and precipitating by sulphide of hydrogen, in the way already pointed out, a known quantity is to be taken and introduced into a porcelain crucible, furnished with a lid, adapted to receive a porcelain tube, the other end of which is connected with an apparatus for generating hydrogen. When the whole apparatus has been filled with this gas, if the crucible be slightly heated, the hydrogen in contact with the sulphide unites with the sulphur, forming sulphide of hydrogen, and metallic antimony is left. A more convenient apparatus for this purpose is seen in Fig. 127 annexed. The flask, *a*, contains water and a few bars of zinc; sulphuric acid is poured in through the funnel, *b*, in order to generate the gas, which escapes by a tube opening just below the cork of the flask, and which is provided with two bulbs, *c c*, where the greater part of the moisture carried away by the gas is condensed. To dry the hydrogen completely, it is conducted through another large tube, *d*, filled with fragments of chloride of calcium, and thence into the bulb, *e*, holding the substance to be reduced. All the bulbs and tubes should be of hard German glass. Before commencing the experiment, the bulb, *e*, with its glass tubes attached, should be thoroughly cleaned, dried, and weighed, and the sulphide of antimony then introduced, taking the precaution that none of the substance remains in the tubes; if it should happen that a little adheres, a feather will push it forward to the bulb. The bulbed tube and its contents are now reweighed, and the increase of weight is the quantity of the compound submitted to experiment. The various parts of the apparatus are next well connected by means of caoutchouc tubes, as seen in the figure, and the hydrogen generated; as soon as the apparatus is filled with the gas, a gentle heat is applied by means of a spirit-lamp, *g*, to the bulb containing the substance, till the reduction is completed. If the compound consists of tersulphide of antimony, scarcely any sulphur is sublimed during the reduction, as it passes off in the form of sulphide of hydrogen; but should the higher sulphurized compounds of antimony be present, sulphur will be sublimed at the same time that the remaining part unites with the hydrogen and escapes. The sublimed sulphur is expelled by bringing the heat of the lamp gradually towards that part of the tube where it is deposited. When it is observed that no more sulphur condenses in the tube, and that sulphide of hydrogen ceases to be evolved from the extremity, the apparatus is allowed to cool, but the current of hydrogen is still maintained. As soon as the apparatus is perfectly cold, it is taken to pieces, the bulb-tube, *e*, wiped clean and weighed; the difference between the weight of the bulb-tube and substance before the experiment, and that which is now obtained, is the amount of sulphur in the sulphide submitted to reduction, and the difference between the weight of the empty tube, and its weight after the reduction, is the weight of the metal yielded by the sample operated upon; hence, as in the case of the sulphate of baryta, the per centage of antimony in the sample is calculated from this determination. Considerable care must be exercised in the reduction of the sulphide of antimony by hydrogen gas, in order to arrive at accurate results: indeed, it is almost impossible to prevent the sublimation of a small portion of metallic antimony, if the heat applied be at all higher than the required degree; and on the contrary, if it be too feebly applied, part of the sulphur remains without being expelled, and for this reason the weight of antimony obtained is too great.

Fig. 127



Another source of error is, that the hydrogen carries portions of the metal with it in combination, in the form of terhydride of antimony, which may be proved by igniting the gas as it is discharged from the end of the tube, when very slight but perceptible fumes of teroxide of antimony will be observed; and if a cold porcelain surface be held over the flame, the metal will deposit upon it in the form of a black spot. Hence, in most analyses, the operator invariably finds a little less of metal and more sulphur than the compound really contains, as the sulphur is calculated from the loss which the body suffers during heating. When a strictly accurate determination is not so much sought, with ordinary care the method here laid down answers the purpose. If the heat be applied slowly at first, and then kept incipient till the greater part of the sulphur is expelled, raising it after that time till the bulb becomes slightly red, the loss of antimony will not exceed half a per cent. The reduced metal does not fuse into a globule, but remains in the form of small metallic grains; and if the heat applied during the time the hydrogen is forced through the apparatus be slow and continuous, the reduced metal presents crystalline facets, the lustre of which causes the antimony to appear blacker than when it is reduced under the influence of a stronger heat.

When antimony is alloyed with other metals, or associated with them in mineral substances, its amount may be determined—except when united to tin—by dissolving the substance in nitric acid, or in aqua regia containing an excess of nitric acid; the antimony by this treatment is converted into teroxide of antimony, which precipitates, while the other oxides are dissolved in the liquid. Before the whole of the antimony is thrown down, however, it is necessary to decompose any terchloride that may be formed—when aqua regia has been used as the solvent—by evaporating the liquid with an excess of nitric acid. The residue is then thrown upon a filter and washed with water, dried, and its weight determined, after which a portion is taken, and reduced by hydrogen in the way already described.

This method does not yield strictly accurate results, on account of the precipitated teroxide of antimony not being perfectly insoluble in nitric acid, and, therefore, the filtrate and washings always contain some traces of antimony; yet, for technological purposes, the results obtained are sufficiently correct.

In scientific investigations, the solution of the metals should be treated with ammonia in slight excess, then with a strong solution of sulphide of ammonium, containing an excess of sulphur, which dissolves the antimonial body, leaving the sulphides of the accompanying metals. By filtering off the solution, and washing the residue, first with dilute sulphide of ammonium, and then with water, the whole of the antimony is removed; the washings and filtrate are now mixed, hydrochloric acid added in slight excess, and a gentle heat applied as long as sulphide of hydrogen is evolved, by which the sulphide of antimony is thrown down; it is to be collected on a dry tared filter, washed with a little sulphide of hydrogen water, dried at 212° till the weight remains constant, and then reduced in the way already explained. Antimony is removed by this process from lead, silver, mercury, bismuth, copper, iron, nickel, cobalt, and manganese.

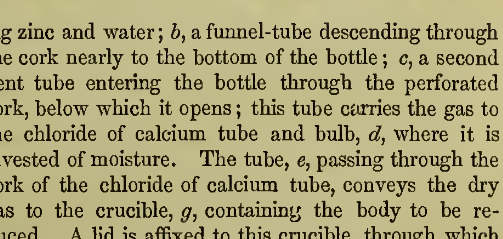
If antimony has to be separated from tin, ROSÉ recommends the appended process:—When both metals are alloyed, he treats the mass cautiously with nitric acid, and after the violent oxidation has terminated, evaporates the liquid at a gentle heat. When perfectly dry, the mixed oxides thus obtained are to be fused in a silver crucible, over an Argand lamp, with an excess of hydrate of soda; the fused substance is to be softened with a large quantity of water, gently warmed, and the antimoniate of soda allowed to subside. After the liquor becomes perfectly cold, the clear solution is filtered off, and the precipitate retained still in the beaker is treated a second time with water, which is filtered from it as before.

In this way the whole of the stannate of soda is removed, and antimoniate of soda left. As soon as the liquid remains opaque, it is a sign that the whole of the tin salt is dissolved. If the opaque liquid containing the antimoniate of soda were thrown upon the filter, it would pass through owing to its very minute state of division, but upon the addition of a small quantity of a dilute solution of carbonate of ammonia, the liquor quickly clarifies, and may be passed through without fear of the filtrate appearing turbid; the edulcoration should not be continued too long with the carbonate of ammonia, as small quantities of the teroxide are dissolved by this reagent.

The moist antimoniate is now treated in a beaker glass, with a mixture of tartaric and hydrochloric acids, which readily dissolves it; the solution is next filtered, and the paper washed with a dilute solution of the acids, in order to remove any traces of the substance that may have remained adhering to the paper. Sulphide of hydrogen gas is then passed into the liquid, until the whole of the antimony is converted into orange-red sulphide, and the liquor evolves a strong odor of the gas; the beaker is then covered, and left in a moderately warm place on the sand-bath till the free sulphide of hydrogen is expelled, after which the precipitate is collected upon a dry tared filter, exsiccated and weighed, and the proportion of sulphur and metal ascertained by either of the foregoing methods.

ROSÉ reduces the sulphide of antimony in an apparatus such as the annexed—Fig. 128: *a* is a bottle, containing zinc and water; *b*, a funnel-tube descending through the cork nearly to the bottom of the bottle; *c*, a second bent tube entering the bottle through the perforated cork, below which it opens; this tube carries the gas to the chloride of calcium tube and bulb, *d*, where it is divested of moisture. The tube, *e*, passing through the cork of the chloride of calcium tube, conveys the dry gas to the crucible, *g*, containing the body to be reduced. A lid is affixed to this crucible, through which a small porcelain tube, *h*, passes, and which is connected to the pipe, *e*, by a piece of caoutchouc tubing. Before the experiment commences, the crucible with the lid and its tube is balanced, and then the substance introduced, and the whole reweighed; the dif-

Fig. 128.



ference in the two weighings is that of the body taken. All the connections of the apparatus are now made air-tight, and the crucible attached; hydrogen is generated in the bottle, *a*, by pouring sulphuric acid down the funnel tube, *b*, and when the whole apparatus becomes filled with the gas, heat is applied by means of a spirit-lamp, *l*, to the crucible, taking all the precautions previously mentioned. When it is observed that no more sulphide of hydrogen is evolved from the end of the tube, the heat is removed, but the current of hydrogen is maintained during the cooling of the apparatus, after which it is taken asunder, and the crucible with its contents weighed. The calculations are the same as those mentioned in the preceding experiment.

ARSENIC is a metal which is associated with antimony in several ores. The annexed method serves for their separation:—Having dissolved the ore or alloy in aqua regia, sulphides of antimony and arsenic are to be obtained by saturating the solution with ammonia, and then adding sulphide of ammonium containing an excess of sulphur; the menstruum is allowed to digest for some time, then filtered, and hydrochloric acid added to the filtrate in slight excess, to precipitate the dissolved sulphides. The precipitate is collected upon a dry tared filter, washed with water impregnated with a little sulphide of hydrogen, and dried in the water-bath till all moisture is expelled, after which it is weighed. Having found the weight of the mixed sulphides, a portion is taken, and the amount of sulphur in it ascertained by treating a known quantity with aqua regia, till all the sulphur is oxidized, and then with chloride of barium, tartaric acid being previously added to prevent the precipitation of any basic terchloride upon diluting with water. The precipitated sulphate of baryta is treated as before directed.

Another portion of the mixed sulphides is introduced into the bulb tube—Fig. 127—and a stream of hydrogen gas passed over it, while a proper heat is applied by the lamp; all the sulphide of arsenic, with the excess of sulphur, is expelled, leaving sulphide of antimony, which is to be weighed.—*Noad.*

This method, according to ROSÉ, gives very accurate results when performed with ordinary care. From the loss sustained by the weight of sulphide taken in the last experiment, and which is sulphur and arsenic, the proportion of sulphide of antimony is known; and since the amount of sulphur in the entire substance has been already ascertained, by deducting it from the combined weight of the sulphur and arsenic, as before ascertained, the difference is the arsenic.

DRY ASSAY OF ANTIMONIAL ORES.—All the ores of antimony, for the purpose of assay, may be divided into two classes—those in which the metal is combined with oxygen or chlorine, and in which little or no sulphur is present; and those compounds of sulphur and the metal, which include all those other minerals compounded of antimony, and other metals united with sulphur.

All the ores belonging to the first class are very easily reduced—provided no earthy or silicious matters are present—by simply heating them to redness with finely divided charcoal, and the assay may be conducted in an earthen crucible; but as antimony is so readily volatilized, care must be taken that the heat is not too high during the reduction. If the ore contain calcareous or silicious impurities, it is necessary to mix it either with three parts of black flux, or one of carbonate of soda, and one-fourth part of charcoal finely ground. In this case the lining of the crucible with charcoal powder may be dispensed with, as it may be introduced at once into the fire, and left there till the content is in a tranquil state of fusion; it is then to be withdrawn, and gently tapped against some hard substance while hot, to cause the small globules of antimony to unite and form one button at the bottom.

The crucible is broken as soon as it gets cold, and the metallic button at the bottom carefully freed from adhering matter, by gently tapping it with the hammer, brushing off dust, or other adhering matter, and weighed. Unless great delicacy of manipulation be observed when detaching the slag, portions of the metal will be removed on account of the brittleness of the antimony rendering it liable to the detachment of small particles, which, of course, would be so much loss. Substances, principally consisting of teroxide of antimony, but which contain small quantities of sulphur, may be analysed by the foregoing method; for as the sulphide yields to the black flux just half its combined antimony, a very small portion only can be retained in the slag. When oxide of iron is present in abundance, this metal is liberated simultaneously with the antimony, and both uniting, form an alloy, which, if weighed as being entirely antimony, will afford wrong results.

Ores of the second class offer more difficulties than those just described. Their assay may be performed either by first roasting the sulphide, and subsequently fusing the oxide produced with black flux, or by directly treating the mineral, reduced to an impalpable powder, with finely divided metallic iron or iron scales, and a little black flux, at an elevated temperature.

As the sulphide of antimony is very fusible and volatile, it requires much care and attention to roast it thoroughly, in order to expel the sulphur, and form the teroxide of the metal; to be successful, the temperature should be moderate, and the mass kept stirred with an iron rod or wire, as long as any sulphurous vapor rises. When these cease to be evolved, the residue is fused with three parts of black flux in the usual way, by which a button of antimony is obtained.

Sulphide of antimony is reduced with facility, by fusing it with minutely divided metallic iron, such as filings, *et cetera*. The sulphide of iron resulting from the decomposition, has a specific gravity closely corresponding with that of metallic antimony, and hence it becomes difficult to remove the metal, unless the contents of the crucible be kept fluid for a considerable time at a moderate heat. When this precaution has been taken, two distinct masses are observed on breaking the crucible; the bottom one, which is antimony, being of a white color, and crystallized in plates, while the other has a bronze yellow tint, and is composed of sulphide of iron, containing a small proportion of metallic antimony. The quantity of antimony is ascertained by carefully detaching it from the sulphide of iron, and weighing.

Accurate results are not, however, obtained by this method, as the prolonged heat, however carefully attended to, sublimes some of the metal. In reducing sulphide of antimony by metallic iron, it is necessary to proportion the weight of iron used to the sulphur in the ore, as, from the great tendency of the antimony to form an electro-negative element, it would unite with the excess of iron and form an antimonide of iron, which would render the remainder impure; it is likewise necessary to have the iron as free as possible from rust or sesquioxide, in order that it may effect the decomposition as rapidly as possible, for then the less antimony would be lost by sublimation. Cast-iron cannot be used to decompose sulphide of antimony, as sulphur has but very little effect upon it, unless at a high temperature, and then the slag adheres so tenaciously to the reduced antimony, that it cannot be accurately detached.

Much of the inconvenience attending the reduction of the sulphide of antimony by means of iron, may be avoided by mixing with the reducing agent a carbonate of soda, which lessens the density of the slag and increases the fusibility of the mass. To gain this point, the alkali is mixed with the antimonial body, and the mixture subjected to heat till it liquefies, and when this happens, the proper weight of iron is introduced; metallic antimony readily separates, and the slag, which is now a double sulphide of iron and sodium, is as fusible as was the double sulphide of metal and antimony previous to decomposition; such a slag affords great facility for the metal assuming the form of a globule or button at the bottom of the crucible or cupel. Similar changes take place when the sulphide of antimony, iron, and carbonate of soda are mixed at once, previous to the application of heat. Although the carbonate of soda favors the decomposition of sulphide of antimony by iron, yet great care must be taken when it is employed, particularly when the iron is used only in proportion to form sulphide, with the sulphide in combination with the antimony, as it produces a slag containing a large quantity of antimony. For reducing pure sulphide of antimony, the best and most economical amount is from forty-five to fifty parts of the alkaline carbonate, with forty-two of iron, and five of finely divided charcoal for every hundred parts of the ore. On subjecting this mixture to heat in a crucible lined with charcoal, it readily affords from sixty-five to sixty-seven per cent. of regulus of antimony. Oxide of iron may be used in this operation, but the charcoal must be added in larger proportions.

When iron scales are used, it is necessary to take forty parts to every hundred of the ore, and this mixture, on being fused with one hundred parts of carbonate of soda and fifteen of charcoal, affords between sixty-five and sixty-seven per cent. of metal.

Cyanide of potassium has been lately introduced into the assaying of antimonial sulphides with decided advantages over the other methods, as the heat required to effect the reduction is much lower, and the operation is performed quicker than by any of the foregoing processes.

Mitchell recommends four parts of the cyanide to a hundred of the sulphide, and upon gently heating the mixture in an earthen crucible for a short time, the metallic antimony is obtained.

The dry assay of antimonial combinations gives only a wide approximation to the truth; hence, when strict accuracy is required, recourse must be had to the humid analysis.

The importation of antimony ore annually averages about one thousand tons, which is chiefly from Borneo. The price varies, according to its richness and supply, from £10 to £14 per ton, and that of metallic antimony from £38 to £48 per ton.

ARSENIC.—*Arsenic*, French; *arsenik*, German; *arsenicum*, Latin.—The word arsenic occurs first in the writings of Dioscorides, and some of the authors who lived about the commencement of the Christian era. In those works the word denotes a reddish-colored mineral, composed of arsenic and sulphur, used medicinally by the ancients, and also in painting.

This substance is peculiar to the mineral kingdom. It is found in the elementary state, and in combination with oxygen, sulphur, and other bodies.

The distinct metallic characters of arsenic were discovered by Brandt in 1773, who gives the first accurate process for procuring it. He mixed white arsenic —arsenious acid—with potassa and chloride of ammonium, and fused the mixture in a well-luted crucible. Its properties were further investigated by Macquer, in 1746; by Munnet, in 1773; and by Bergmann, in 1777; but the latter took many of his facts from Brandt's paper.

To the labors of these philosophers, and likewise to those of Scheele, science and art are indebted for almost all that is known of the properties of this element.

Its general chemical relations are such as to place it rather among the simple acidifiable bodies than among the metals, for it forms no salifiable base with oxygen, but constitutes acids; it possesses, however, the lustre and opacity of a metal, and conducts electricity.

There are two native compounds of it with oxygen, namely, arsenious and arsenic acid, the latter being found with bases, forming arseniates. Orpiment and realgar, two of its sulphides, are also met with in the mineral kingdom. Some time ago, M. Tripier detected arsenic in the mineral waters of Meskoutine, in Algiers, and Walchner has found that small quantities of arsenic always accompany iron, and frequently influence its quality. It is often found in combination with metallic sulphides, especially with the sulphide of iron, constituting arsenical pyrites. It will be well to append the principal modifications of this element:—Native arsenic, arsenious acid, arsenic glance, realgar, orpiment, arsenical pyrites, bright white cobalt, tin white cobalt, bismuth cobalt ore, nickel ochre, polybasite, red silver, and various other compounds; as arsenic acid in arseniate of copper, of which several varieties are known; in euchroite, kupferschaum, erinite, scorodite, and in various other combinations.

The metal is easily prepared in the laboratory, by mixing one part of pure arsenious acid with three of black flux in a crucible, on which another of a similar shape is inverted as a head, and applying a moderate heat, either in a furnace or over a lamp. By keeping the cover as cool as possible, the metal will be found in the course of a short time sublimed, and adhering to the interior of the crucible, in the shape of a glassy coating of a brilliant metallic appearance.

Charcoal, or oil, may be substituted for the black flux if requisite, and similar results are obtained upon distilling from a retort of hard glass.

Arsenic is of a bluish-white color and crystalline texture. It is the most volatile of all the metallic bodies, and is so brittle that it may be easily reduced to a fine powder by trituration in a mortar. Kept in water, it suffers no alteration; but when exposed to the air, it soon loses its lustre, becomes black, and falls to powder. It volatilizes—seemingly before fusing—at a temperature of about 360° Fahr. When exposed to a moderate heat in contact with air, it sublimes in the form of a white powder, and at the same time emits a most characteristic alliaceous odor. If the heat be increased, it burns with a pale blue flame—arsenic, indeed, is one of the most combustible of the metals.

The substance which sublimes was formerly called arsenic, or white arsenic, and is still known by those names in the commercial world; but this is now denominated arsenious acid. It is seldom prepared by chemists, because it exists native, and is often procured in great abundance during the extraction of the metals from their ores.

ORFILA states that metallic arsenic, when swallowed, is capable of acting as a powerful poison, probably by being oxidised into arsenious acid.

The specific gravity of arsenic is 5·96, and of its vapor, 1·0362, air being unity.

Heated in an atmosphere of oxygen gas, arsenic burns with a bluish flame; with chlorine it ignites spontaneously, producing a brilliant white flame, and arsenious acid. It is soluble in nitric acid and in aqua regia, and is converted by this treatment into arsenious or arsenic acid, according to the more or less prolonged action of the solvents. It enters into fusion with most of the metals, and, by this union, renders those which were malleable, more brittle, and those before difficultly fusible, more easily melted; it also confers a brightness upon the alloy, which often renders its presence in small quantities desirable.

The metal is prepared on the large scale by subjecting native arsenic, or arsenical iron, to sublimation in earthenware retorts, to which are attached receivers, wherein a piece of rolled sheet-iron is generally placed to collect the whole or greater part of the sublimate. The other methods do not differ from the preceding process for reducing arsenious acid, except that, on the large scale, the product is impure.

Those compounds of arsenic which are the objects of manufacture, and which are applied, to a considerable extent, in the arts, are arsenious acid, and its combinations with other metallic bases, such as copper, cobalt, chromium, *et cetera;* sulphides of the metal, such as orpiment and realgar, and some few others which will be described in the succeeding pages.

ARSENIOUS ACID.—*Acide arsenieux*, French; *arseniksäure*, German; *acidum arseniosum*, Latin.—Arsenious acid, white arsenic, and white oxide of arsenic, are synonymous.

This compound is formed, as previously stated, when arsenic is heated in the open air; it sublimes in white fumes, and, when collected, constitutes arsenious acid. It is usually in the form of a compact white cake; but it may also be obtained crystallized in octahedrons.

It has an acrid taste, which ultimately leaves an impression of sweetness, and it is one of the most virulent of poisons. Arsenious acid is composed of one equivalent of arsenic and three equivalents of oxygen, as shown by the analyses of MITSCHERLICH and BERZELIUS:—

		Centesimally represented.		
	Atomic weight.	Theory.	Mitscherlich.	Berzelius.
1 Eq. arsenic,........	75 ..	75·76 ..	75·730 ..	75·782
3 Eq. oxygen,........	24 ..	24·24 ..	24·270 .	24·218
1 Eq. arsenious acid,..	99	100·00	100·000	100·000

It is prepared in several other ways besides those previously given. The readiest way to proceed in the laboratory will be to dissolve the metal in nitric acid, and evaporate the liquid to perfect dryness to expel the whole of the nitric acid; the residue should be washed with a little water, in order to remove any adhering nitric acid, after which it is dried, and retained carefully for use.

Arsenious acid is soluble in boiling water to a moderate extent, but considerably less so in cold; it is also soluble in alcohol and oils. Regarding the solubility of arsenious acid, GUIBOURT found that the vitreous acid required 104·17 parts of water at 60° Fahr., and the opaque 80 parts. Boiling water dissolved 9·68 of the former, and 11·47 parts of the latter; the solutions, upon being cooled at 60°, retained 1·78 of the vitreous, and 2·9 of the opaque. This authority further states, that the color of litmus paper was only faintly tinted red by the solution of the vitreous, and not at all by that of the opaque acid, but paper slightly reddened was turned blue by it; both solutions, however, communicate a feeble acid reaction to blue litmus paper.

Arsenious acid is found in two distinct conditions—crystallized and amorphous. The crystallized acid often assumes two forms; the octahedron and tetrahedron. —Figs. 129 and 130. WÖHLER has observed that the acid assumes the form of hexahedral plates, derived from the right rhombic prism; hence it appears to be dimorphous, which seems connected with the peculiarities of the opaque and vitreous state of the acid.

Fig. 129.

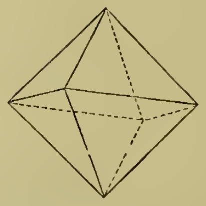
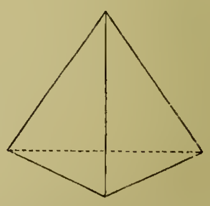


Fig. 130.



Vitreous arsenious acid, when recently prepared, is in the form of large, glassy, colorless, transparent cakes; it is sometimes of a yellowish color, and in concentric laminæ formed by successive sublimations. By exposing these transparent cakes to the air, they are readily covered with a white coating, and lose their former transparency. This change is gradually extended to the centre, so that the fracture has an enamel-like appearance; occasionally, the cakes crumble down into a friable mass. The reason of this change has been ascribed by Kruger to the absorption of water, as, according to that chemist, no change takes place in perfectly dry air; he ascertained that the acid increased in weight, though not more than a one hundred and sixtieth of the whole mass.

Various results have been arrived at by different chemists respecting the specific gravity of arsenious acid. The gravity of the opaque acid is, according to

Guibourt,	3·695
Taylor,	3·529
Brandt,	3·600

The gravity of the transparent acid is given by

Dumas,	3·698
Guibourt,	3·738
Brandt,	3·700

Pereira kept arsenious acid in a sealed tube for two years without any change being noticed, but on cracking the tube the transparency of the enclosed acid was, in a very short time, lost.

A singular property of arsenious acid observed by Rosé is, that when the vitreous acid is dissolved in hydrochloric acid, and allowed to cool slowly, vivid flashes of light are emitted from the crystals as they form. The phenomenon does not attend the crystallization if the opaque acid is dissolved in the acid liquor, neither will it succeed if the crystals deposited from the vitreous substance be redissolved in the acid, and suffered to cool as they acquire the property of the opaque acid; the production of the light seems to be connected with the transition from one modification to the other.

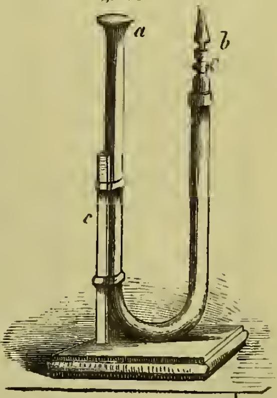
Heated on charcoal before the blowpipe, it emits the peculiar characteristic arsenical odor; when mixed with carbonate of soda and charcoal, and the compound subjected to heat in a glass tube, it yields a ring of metal which condenses on the cold part of the tube. Arsenious acid is decomposed at an incipient red heat by hydrogen, carbon, and many of the metals.

Sulphide of hydrogen produces, in solutions of arsenious acid, a lemon-yellow precipitate of tersulphide of arsenic, which is very characteristic of this body; the yellow tint being observed when a ten-thousandth of the acid is present, and a precipitate becoming visible in an acidulated solution of one part of arsenious acid in eighty thousand parts of water. Excess of lime-water occasions a white precipitate in a liquid containing about one five-hundredth of arsenious acid. Ammonio-sulphate of copper gives an apple-green precipitate in a solution of arsenious acid, thus indicating about a twelve-thousandth part of the acid; and according to Reinsch, when a slip of bright copper leaf is boiled in an aqueous solution, acidulated by hydrochloric acid, a grey film of arsenic is deposited upon the copper, showing the presence of less than a one hundred-thousandth part of the acid. Nitrate of silver gives with it a yellow precipitate.

The Editor considers the most infallible test to be the characteristic alliaceous odor which is evolved when this substance is heated before the blowpipe; he has several times astonished parties with the minute quantities of arsenic that could be detected, on submitting substances containing it to the action of reducing agents before the blowpipe flame.

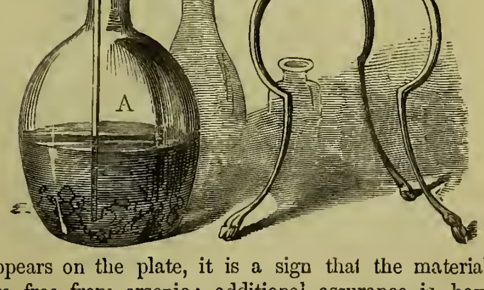
Arsenic forms a gas with hydrogen; the combination of the two elements may be effected by bringing together arsenious acid, or an arsenical compound, with zinc, water, and sulphuric or hydrochloric acid. This property was first taken advantage of as a test for the metal by the late Mr. Marsh, of Woolwich. The apparatus he employed is shown in an improved form in Fig. 131. The stopcock, *b*, being removed, a few fragments of depurated zinc are introduced into the bend, and pure dilute sulphuric acid poured upon them; the part, *b*, is fixed on, *a* is closed with the thumb, and the gas evolved having been proved to be free from arsenic, by no deposit being formed when burned against a porcelain plate, the suspected liquid is then examined in a similar manner.

Fig. 131.



Any apparatus, based on the same principle as the above, is called after Marsh. Fig. 132 is a convenient form. The materials for generating the hydrogen are introduced into the evolution flask, A, and the gas, discharged through a tube, B, filled with dry cotton-wool, is—sufficient time being allowed to expel the atmospheric air from the apparatus—inflamed at the point of the bent tube, C, and a porcelain plate depressed on the flame. If, after burning for some time, no incrustation or blackening appears on the plate, it is a sign that the materials are free from arsenic; additional assurance is, however, obtained by heating a portion of the horizontal tube to redness at *b*, by means of a spirit-lamp; no

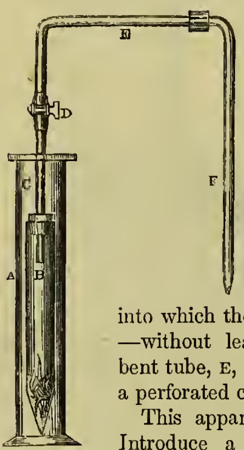
Fig. 132.



incrustation must be observed in the tubes. The liquid to be tested for arsenic is now introduced into the evolution flask through the funnel tube; and if it contain any traces of the poison, the flame of the hydrogen will acquire a bluish-white color, owing to the reduction and separation of the arsenic, and fumes of arsenious acid will make their appearance. On bringing the porcelain plate in contact with the flame, brown arsenic spots, having a shining metallic appearance, will be obtained.

On directing the flame of the spirit-lamp to the horizontal part of the tube, a beautiful incrustation of metallic arsenic, *d*, will be formed in the cold part; and on cutting off the end near the deposit, and applying heat, the arsenic is converted into arsenious acid, which may be dissolved in hot water, and tested by nitrate of silver and sulphate of copper.

Fig. 133.



The following—Fig. 133—is the modification of Marsh's apparatus, as given by Dr. Ure:—A is a narrow glass cylinder, open at the top, about ten inches high, and one inch and a half in diameter inside. B is a glass tube about one inch in diameter outside, drawn to a point at the bottom, and closed with a cork at the top. Through the centre of this cork, the small tube, C, passes down air-tight, and is furnished at the top with a stopcock, into which the small bent hard glass tube —without lead—E, is cemented. The bent tube, E, is joined to the end of F by a perforated cork.

This apparatus is used as follows:—Introduce a few oblong slips of zinc, free from arsenic, into B, and then insert its cork with the attached tubes. Having opened the stopcock, pour into the tube, A, as much of the suspected liquid, acidulated with dilute sulphuric acid, as will rise to the top of the cork after B is full, and immediately shut the stopcock. The generated hydrogen will force down the liquid out of the lower orifice of B into A, and raise it above the level of the cork. The extremity of the tube, F, being dipped beneath the surface of a weak solution of nitrate of silver, and a spirit flame being placed a little to the left of the letter E, the stopcock is then to be slightly opened, so that the gas which now fills the tube, B, may escape so slowly as to pass off in separate small bubbles through the silver solution. By this means the whole of the arsenic contained in the terhydride of arsenic will be deposited either in the metallic state upon the inside of the tube, E, or with the silver will pass into the characteristic black powder. The first charge of gas in B being expended, the stopcock is to be shut till the liquid is again expelled from it by a fresh disengagement of hydrogen.

The ring of metallic arsenic deposited beyond E may be chased onwards, by placing a second flame under it, which forms it into an oblong, brilliant, steel-like mirror.

It is evident that, by the patient use of this apparatus, the whole arsenic in any poisonous liquid may be collected, weighed, and subjected to every kind of chemical verification. By means of the perforated cork, the tube, F, may readily be turned about, and its taper point raised into such a position as that, when the hydrogen issuing from it is kindled, the flame may be made to play upon a surface of glass or porcelain, in order to form the arsenical mirror.

Arsenious acid unites with most bases, with which it forms salts, called *arsenites*. With oxide of copper it gives compounds much used as pigments, and which will be hereafter described.

Arsenious acid is manufactured on the large scale only in a few establishments; it is, however, obtained as a secondary product in many metallurgic operations, such as those of cobalt, the ores employed containing a large proportion of arsenic. The principal places where the acid is prepared to a large extent are, Altenberg and Reichenstein, in Silesia, where the most improved methods are followed, as arsenious acid is the sole product of the manufacture. Arsenical iron, which is the ore employed, is coarsely ground, or broken up into small pieces, previous to its being introduced into the furnace, in which state it is called *schliech.* The roasting of the arsenical ore is somewhat similar to the manner of burning sulphur for the manufacture of sulphuric acid, but the fire is kept out of contact with the former, while it acts directly on the latter. In the succeeding figures, the kind of apparatus used is represented.

Fig. 134.

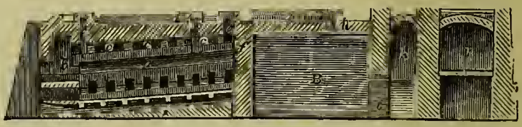
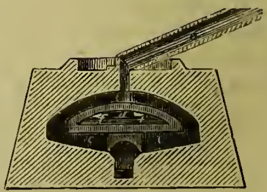


Fig. 135.



Figs. 134 and 135 are explanatory of the furnace: the first shows a longitudinal, and the second a transverse section; the same characters in each indicate the same parts. The muffle of the furnace, where the ore is deposited for roasting, is indicated by *a*; *b* is a door in the front of the muffle, through which the workman introduces his slicer to work the charge, and draw out the exhausted material; *c c c* are the flues round the muffle, where the smoke and flame from the fire are carried forward to the main flue, *e*, leading to the chimney. From the muffle, two channels, *f f*, lead to two others, *g*, and these terminate in a larger one, *h*, which opens into the first chamber, B, appropriated for the condensation of the acid. By the opening, *i*, the vapors of the acid uncondensed in B pass into the conduit, *k*, and thence by *l*—Fig. 136—into the lower of the compartments, *m n o p q r*, which compose the poison tower, where most of the gases evolved from the muffle are condensed. The sulphurous acid arising from the oxidation of a portion of the sulphur escapes through the top.

About ten hundredweight of the prepared ore—schliech—form the charge, which is introduced through the opening, *d*, and spread upon the inclined hearth of the furnace to the depth of from two to four inches. At first the application of the fire is well attended to, till the mass in the muffle approaches a red heat, after which it is abated to a certain degree, and maintained at that point till the whole of the charge is worked off, and this is effected in about twelve hours. The exhausted ore is now raked out at the front, and another charge introduced as before. During the roasting of the ore, the door, *b*, is kept open, that the air entering may oxidize the metals, and particularly the arsenic. The current of air is rendered more forcible in consequence of the heat in the furnace, and the declination of the hearth towards the front of the muffle. Frequent stirring of the metals is necessary to insure their complete oxidation.

Fig. 136.

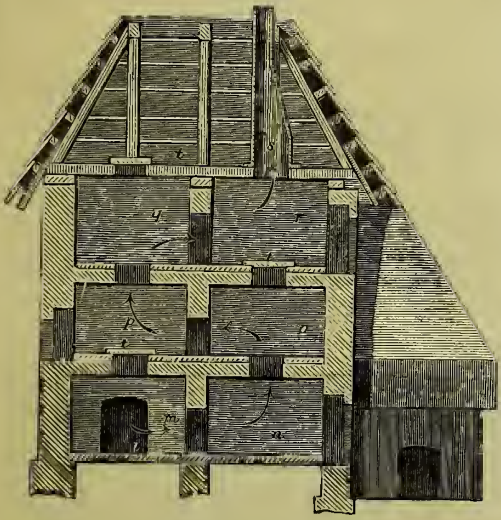


Fig. 136 is a section of the *poison tower*, where the arsenious acid is condensed in the spaces, *m n o p q r*; the fumes, as stated above, enter the lower compartment at *l*, and then follow the direction of the arrows, until, finally, the uncondensable vapors depart through the opening, *s*. In the flues and first chambers of the tower, the purest arsenic is to be found, that which is deposited in the upper ones being impregnated with sulphur. At the termination of the working of each charge, the covers, *t t t*, are taken away for the purpose of collecting the whole of the condensed arsenious acid into the lower chamber, which is emptied only about once in every two months, and contains at that period about twenty-five tons of the impure compound. At first sight a great deal of fuel would appear to be consumed; this, however, is not the case. The reason is, that the metals during the oxidation evolve so much heat, that only very little besides is required to maintain the equalized heat necessary to dispel the whole of the volatile products. About four and a half bushels of charcoal are sufficient to oxidize the quantity just mentioned.

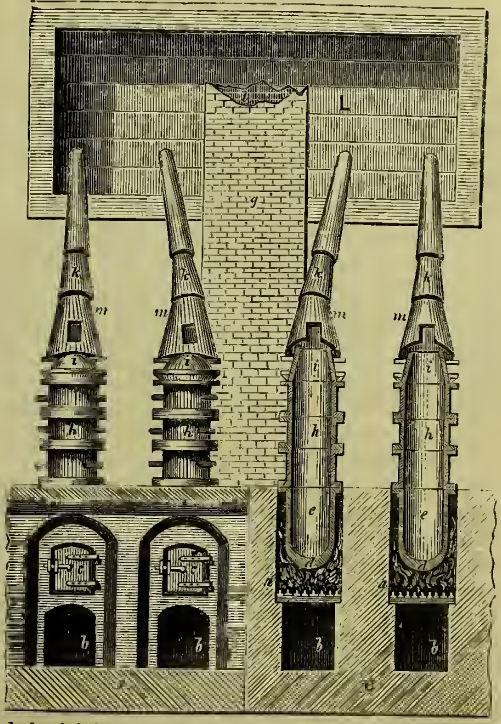
The arsenious acid procured by the foregoing mode is purified, before it is sent to market, by sublimation; the method, together with the representation of the furnace, adopted at Reichenstein for that purpose, are here given.

Fig. 137 is a drawing, which shows the front view of the furnace.

The part A is a front view of the half, and B a section of the other half. The fire-grates are indicated by *a a; b b* are the ash-pits, *c c* the doors, and *d d* the space appropriated for the fire to play under the bottom of the subliming pots; the smoke is carried off by the chimney, *g*. The subliming pots, *e e*, are made of cast-iron—or they may be of porcelain—and receive the crude arsenic to be sublimed; they are surmounted by iron drums, *h h*, serving as condensers, and are furnished with caps, *i i*, which in turn are covered with the funnelled pipe, *k k*, the narrow ends of which enter the condensing chamber, L. In these pipes, *m m* are openings to admit the insertion of a probing wire, to clear them when choked up by the sublimed material.

Each pot is charged with about three and a half hundredweight of the crude arsenious acid; the cylinders, *h h*, are then appended in their proper position by the aid of the handles with which they are supplied, and the joinings being well luted with a composition of loam, hair, and blood, the caps, *i i*, are adjusted, as also the pipes, *k k*, and lastly, the fire is lighted. A very gentle heat is applied for about half an hour, but this

Fig. 137.



may afterwards be raised to a higher degree, sufficient to conduct the operation without a too rapid effect. The arsenious acid by this means rises partly as a dusty white body, and partly assumes the crystalline shape; both forms, however, fuse by the further action of the heat, and give rise to a vitreous homogeneous mass. Only a sublimate of the acid is obtained when the heat is too feeble, and, on the other hand, much of the arsenic is driven into the pipes and condenser, if it rises beyond due limits. At the end of twelve hours the fire is allowed to go out, and when the furnace is cold, the cylinders are lifted off, and the glass of arsenious acid detached. Sometimes this glass is interspersed with dark spots of metallic arsenic; whenever this happens, either the whole compound must be sublimed anew, or those parts picked out, if such an operation is practicable. Good crude arsenious acid yields from three-fourths to seven-eighths of its weight of the purified substance.

Arsenious acid is used in considerable quantities for the purpose of destroying the color communicated by protoxide of iron in glass-making; in the preparation of various arsenical compounds, some of which are used extensively in printing; and by naturalists, to preserve organic specimens from putrefaction and the ravages of insects. In medicine, it is used only to a limited extent. It exerts a most destructive influence on the system.

ARSENIC ACID.—*Acide arsenique*, French; *arsensäure*, German; *acidum arsenicum*, Latin.—This acid was discovered by SCHEELE, who directed for its ready formation that arsenious acid should be dissolved in aqua regia—nitro-hydrochloric acid—and the mixture distilled to dryness in a retort, which leaves solid arsenic acid. The easiest method, however, of procuring this acid is, to dissolve arsenic in nitric acid, and to evaporate the solution to dryness. The taste of the acid thus prepared is not very remarkable when dry, but when moistened it becomes exceedingly acrid.

Arsenic acid is deliquescent and crystallizable; it fuses at an incipient red heat, concreting, on cooling, into a vitreous mass. At a higher temperature it is decomposed, oxygen is evolved, and arsenious acid sublimes. Its specific gravity is 3·7; six parts of cold and two parts of boiling water are required for its solution, which reddens vegetal blues, tastes acid and metallic, and is a more virulent poison than arsenious acid. It gives a white precipitate with lime-water, a peculiar reddish-brown with nitrate of silver, and gradually yields a yellow deposit of quinquisulphide of arsenic, when its solution is subjected to the action of a stream of sulphide of hydrogen gas. Its precipitate with ammonio-sulphate of copper is pale greenish blue. Arsenic acid consists of—

	Atomic weight.	Theory.	Berzelius.
1 Eq. of arsenic, ...	75	65·22	65·29
5 Eq. of oxygen, ...	40	34·78 ...	34·71
1 Eq. of arsenic acid, ...	115	100·00	100·00

This acid gives salts with bases termed *arseniates*, but they have no commercial importance.

REALGAR.—RED ORPIMENT.—The artificial formation of this compound is not on an extended scale, as it is found in nature in considerable quantities; sometimes associated with native arsenic in veins and efflorescences, and, occasionally, crystalline in primitive mountains. It is most abundant in volcanic districts, as at Solfaterra, near Naples, and is, in some instances, sublimed in the shape of stalactites, as at the craters of Etna and Vesuvius. Natural specimens possess a very beautiful scarlet color, which, when powdered, is changed into an orange red; it is soft, and of a vitreous and conchoidal fracture.

Before the blowpipe it is volatilized, and evolves the peculiar arsenical odor, together with that of burning sulphur.

In the pure state it is composed of —

		Centesimally.	
	Atomic weight.	Found.	Theory.
1 Eq. of arsenic, ...	75	70·0	70·1
2 Eq. of sulphur, ...	32	30·0	29·9
	107	100·0	100·0

Realgar is made artificially, by distilling a mixture of arsenical iron pyrites, arsenious acid, and sulphur. For this purpose a furnace and gallery are erected, in which a number of earthenware retorts are placed, as seen in the annexed cuts—Figs. 138 and 139. The retorts are so disposed that they form two rows, and are composed of silica, iron filings, clay, and alumina, luted to the receivers, which are likewise of earthen or stoneware. A number of small holes permeate the receiver, to allow the gases which form during the distillation to pass off. In the course of the operation, the small holes become choked up from the deposit of sulphide of arsenic which forms on the interior of the vessel; and to prevent an explosion which the confined gases would occasion, the coating of realgar should be scraped off the upper part from time to time by a rod, which may be introduced in an opening for that purpose in the receiver. The retorts are charged to about two-thirds of their capacity with the prepared ore, and the necks adapted to the receivers; a very gentle heat is applied for an

Fig. 138.

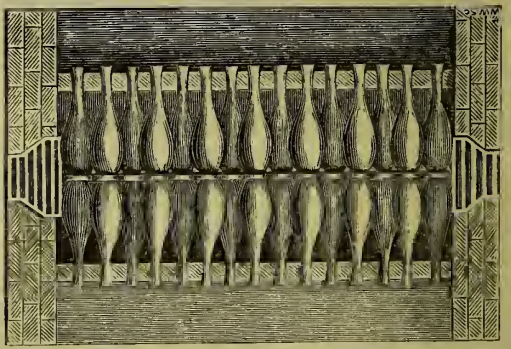
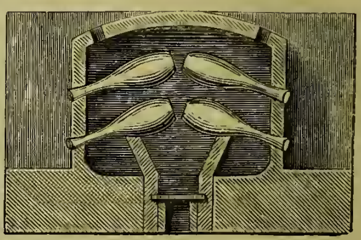


Fig 139.



hour and a half, or two hours, then gradually increased to redness, and maintained so for eight, ten, or twelve hours. During the distillation, the receivers are kept as cool as possible. On withdrawing them at the termination of the process, a yellow and red sulphide of arsenic, together with a red, vitreous, compact body, is obtained; the former is mixed with a fresh charge, and the latter purified for use. The operation is rather dangerous to execute, especially under a chimney having a strong draught. Cast-iron pots or cylinders are employed in the purification, and these are charged with from twenty-five to thirty pounds of the arsenical glass from the first preparation, and heat applied. The attendant ascertains if the proper shade of color is attained by introducing an iron rod into the fused mass; and on withdrawing it, he abstracts part of the compound. If the color be found too dark, some sulphur is added to make it lighter; and if too light, a quantity of a darker realgar is thrown in. When the operation is finished, the realgar is cast into sheet-iron cylinders and allowed to cool, after which it is packed for market. The residue left in the retorts after the first sublimation, consisting of sulphide of iron, *et cætera*, is employed sometimes in the manufacture of sulphate of iron or copperas.

Orpiment.—This is manufactured from the preceding compound of arsenic and sulphur, as also by fusing a mixture of arsenious acid and sulphur in refining kettles similar to those used for purifying arsenious acid. Some conflicting directions have been given for its preparation; as by fusing one part of sulphur with seven of arsenious acid. This might be taken as a misprint, were it not that Guibourt found, upon the analysis of such a sample, ninety-four per cent. of arsenious acid, and only six per cent. of orpiment.

To produce a good article, theory shows that four and a half equivalents of sulphur would be required to one equivalent of arsenious acid; or, numerically, eleven parts of the acid require eight of sulphur to combine with the arsenic and oxygen of the arsenious acid. Experience has proved that the more the manufacturer on the large scale works according to theory, the better and more economical will his trade become.

In making orpiment with realgar and sulphur, seven parts of the former should be taken to one of the latter, and the mixture fused as above. In the moist state, orpiment is prepared by precipitating a solution of arsenic in hydrochloric acid by sulphide of hydrogen, straining off the liquid, and drying the yellow precipitate. Orpiment has a bright yellow color, passing into orange when it is prepared by precipitation, but when obtained by fusion, it is more dark and crystalline after cooling; the fracture is conchoidal. Unlike the precipitated substance, the fused mass is slightly soluble in water, from which sulphide of hydrogen again throws it down as a yellow powder.

It is oxidized by nitric and nitro-hydrochloric acids, and dissolved by alkalies and alkaline carbonates—an arsenite of the base, with sulphide of the alkali metal, being formed, and carbonic acid expelled when the carbonate is used. Heated in close vessels, it fuses and sublimes; in air, sulphurous acid is evolved, and arsenious acid produced.

The composition of orpiment is

	Atomic weight.	Theory.	Berzelius.
1 Eq. of arsenic,..........	75	60·97	61·0
3 Eq. of sulphur,.........	48	39·03	39·0
	123	100·00	100·0

Formula,..................As S_3.

This compound of arsenic and sulphur, like the preceding, is still used, but to a limited extent, as a pigment in oil painting and lacquering. The two are occasionally employed to destroy the effect of the indigo, which is dissolved by the potassa used at the same time. Orpiment was once used to dye silks, by dissolving it in ammonia, and passing the weft through the solution thus produced. On hanging the cloth up in the stove-room, the volatile ammonia was expelled, and the color remained fixed upon the cloth. These compounds are highly poisonous, and should be used with the greatest care.

Arsenites.—Arsenious acid unites with all the mineral bases, and forms with them definite compounds, which, however, are of little utility in a manufacturing or artistic sense, though, as the result of chemical research, they occupy a prominent position in scientific manuals. Those to which any interest is attached are, the *arsenite of potassa*, and the compounds known as *Scheele's green* and *Schweinfurth green*—the former an arsenite, and the latter an arsenite with a portion of acetate of copper.

Arsenite of Potassa.—This substance is formed by dissolving arsenious acid in a solution of caustic or carbonated alkali, and evaporating the solution; or, by decomposing arsenite of baryta by sulphate of potassa, double decomposition takes place:

$$\underbrace{Ba\,O, As\,O_3}_{\text{Arsenite of baryta.}} + \underbrace{K\,O, S\,O_3}_{\text{Sulphate of potassa.}} = \underbrace{K\,O, As\,O_3}_{\text{Arsenite of potassa.}} + \underbrace{Ba\,O, S\,O_3}_{\text{Sulphate of baryta.}}$$

It is the active ingredient in many patent medicines, such as *Fowler's mineral solution*, or *tasteless ague drop*, and is used for the preparation of other arsenites by double decomposition, particularly in the laboratory.

Scheele's Green.—This compound derives its name from Scheele, its discoverer, who gives the following direction for preparing it:—Dissolve two pounds of sulphate of copper in three gallons of warm water; in another vessel make a solution of two pounds of pure potassa, and eleven ounces of arsenious acid in one gallon of water; filter both through a cloth, and while warm, mix them portionwise, keeping the menstruum briskly agitated at each addition. As soon as the precipitate settles to the bottom, the clear liquid is to be decanted or siphoned off, and the green powder treated with a gallon or more of hot water, and agitated. Next it is to be thrown on a filter, again washed once or twice with water, and finally dried at a gentle heat.

Another process followed, is to dissolve two parts of sulphate of copper in forty-four of hot water, and to add to this solution another composed of two parts of carbonate of potassa, one of arsenious acid, and forty-four of water. The green powder which is thus produced is washed well with water, and dried at 212° Fahr.

Schweinfurth Green was first made in the year 1814, at the locality whence it takes its name. It is made by adding a solution of arsenious acid to verdigris. In the cold, the change produced is different from that which subsequently results; a precipitate forms, which, instead of being of the rich color of the compound, has an olive-green tint. This precipitate is, according to ERDMANN, arsenite of copper, and the solution contains the free acetic acid already in union with the base; on leaving the mixture for a long time to react, or by boiling it, a change occurs, and the olive-colored precipitate becomes of a beautiful brilliant green hue. BOOTH directs for its formation, ten parts of verdigris to be diffused through sufficient water to form a thin paste, and this passed through a sieve, after which eight or nine parts of finely-powdered arsenious acid are to be dissolved in a hundred of boiling water, and the solution added while at the point of ebullition to the infusion of the verdigris in water, in successive portions, taking care to stir the mixture well each time; and lastly, the whole is to be boiled for a few minutes, which is sufficient to develop the full tone of color. If cold water be poured into the hot solution without boiling, the peculiar green does not appear for some time; still, a more crystalline compound possessing a richer hue is in this way produced, than by the foregoing method.

BRANDT states another method, which is the following:—Fifty pounds of sulphate of copper and ten of lime are dissolved in twenty gallons of ordinary vinegar, and a boiling hot solution of fifty pounds of arsenious acid in water quickly stirred into it; the precipitate is dried and reduced to powder. In this, the precautions required in the preceding case will be applicable.

ERDMANN gives the annexed composition to the pigment:—

	Centesimally represented.
Arsenious acid,	58·622
Oxide of copper,	31·243
Acetic acid,	10·135
	100·000

Results which correspond with the formula—

$$\mathrm{Cu\,O},\ \overline{\mathrm{A}} + 3\ (\mathrm{Cu\,O},\ \mathrm{As\,O_3}).$$

It should be known that these compounds are highly poisonous, and therefore should be used with caution. It has been stated that these green pigments have been employed by confectioners to give color to their sweetmeats, a practice, if true, fraught with pernicious and fatal consequences.

QUANTITATIVE ESTIMATION.—Arsenic is quantitatively determined in various ways. The following is the method usually followed when no other compound but arsenic or its combinations is present.

In general cases, when the liquor contains other substances not precipitated by sulphide of hydrogen, the arsenical solution may be acidified with hydrochloric acid, and determined by passing through it a current of sulphide of hydrogen. If the liquor be dilute, a precipitate of sesquisulphide of arsenic is produced, the composition of which corresponds to that of arsenious acid. The stream of sulphide of hydrogen is continued until the liquor is completely saturated, the whole is then left at rest in a moderately warm place until the odor of sulphide of hydrogen has vanished, when the traces of sulphide of arsenic held in solution by the excess of the precipitant are thrown down. A small portion of the precipitate adheres so strongly to the side of the vessel, and of the glass tube which dips in the liquor, that it cannot be removed by mechanical means, but it is very easily dissolved by a few drops of ammonia; this solution is added to the acid liquor, which precipitates the small quantity of dissolved sulphide of arsenic. If the liquor contains any oxide of cobalt which is to be subsequently determined, a solution of carbonate of soda must be employed instead of ammonia, for the purpose of dissolving the small quantity of sulphide of arsenic just mentioned, because oxide of cobalt cannot be precipitated completely by potassa from a solution which contains ammonia.

The sulphide of arsenic obtained, is collected upon a tared filter, washed, dried at a very gentle heat, and then weighed. Were the operator quite sure that the solution contains arsenious acid only, he might calculate the quantity of this acid from that of the sulphide of arsenic produced, though even in that case the results would be erroneous, as the sulphide contains more sulphur than is found by calculation, being mixed with a little sulphur due to the decomposition of the excess of sulphide of hydrogen in the liquor. Whenever it is presumed that the solution contains a little arsenic acid, besides arsenious acid, the sulphide of arsenic obtained must be completely analysed, which, for the reason just stated, should always be done, even when the liquor contains arsenious acid only. The best method of performing this analysis is as follows:—

After having dried and weighed the sulphide of arsenic, all that can be shaken from the filter is put into a small matrass, or a large glass vessel, and the filter is again weighed in order to know the amount of substance submitted to experiment. Aqua regia is then poured upon it, and the whole left to digest for some time. The action of the acid upon sulphide of arsenic in fine powder is very energetic, even in the cold, owing to which the oxidation must be performed in capacious vessels. The arsenic is oxidized into arsenic acid, and a portion of the sulphur is converted into sulphuric acid, the remainder continuing in the pure state. In order to convert the whole of the sulphur into sulphuric acid, the digestion in aqua regia, which should be frequently renewed, would require too long a time. On this account, as soon as the sulphur is agglomerated into small lumps, it is collected upon a counterpoised dry filter, washed, dried most carefully, and weighed. A solution of chloride of barium is added to the filtered liquor, and the sulphate of baryta determined with the usual precautions; from its weight, that of the sulphur in solution is calculated. The sulphate of baryta is very difficult to wash, on account of the presence of nitric acid in the solution. The collective quantities of sulphur indicate that which existed in the sulphide of arsenic subjected to analysis; the loss indicates the loss of the arsenic, from which the proportion of the arsenious acid is calculated. It is necessary to take care in this operation, to collect the undissolved sulphur only after a prolonged digestion in aqua regia. The color of sulphide of arsenic does not differ much from that of sulphur, yet a little practice enables the operator to detect very readily whether the sulphur contains any of the metallic compounds.

Instead of the preceding, the following method may be adopted:—The acid liquor is supersaturated with ammonia, and a quantity of sulphide of ammonium is added thereto, which produces a precipitate of sulphide of arsenic, dissolving easily and completely in the excess of sulphide of ammonium, whether it be tersulphide or quinquisulphide of arsenic.

If the solution is very concentrated, it should be diluted with a large quantity of water, and hydrochloric acid carefully added, till it gives a feeble acid reaction with litmus paper. Sulphide of arsenic is thereby precipitated, with disengagement of sulphide of hydrogen. The liquor is digested at a gentle heat, until the odor of the sulphide of hydrogen has disappeared, and the sulphide of arsenic produced is separated by filtering.

Ordinarily, arsenic acid is precipitated by a solution of acetate or nitrate of lead, in the state of arseniate of lead, from the weight of which the quantity of the arsenic is determined; but this method is seldom satisfactory, and is attended with more difficulties than that just described, when the solution contains other metallic oxides.

It is absolutely necessary to analyse this sulphide, as before said, because it is mixed with much sulphur from the decomposition of the sulphide of ammonium. If the operator has not added a very large quantity of water to the solution of the sulphide of arsenic in sulphide of ammonium, before decomposing it by hydrochloric acid, and too large a proportion of this acid is subsequently added, the whole of the arsenic is not obtained in the state of sulphide. It is better, in a great number of cases, to decompose the liquor with acetic, instead of with hydrochloric acid. The sulphide of arsenic is much more completely precipitated by this than by the foregoing course of analysis.

It is also necessary to determine the quantity of the arsenic acid in the arseniate of lead produced, in order to obtain anything like tolerable accuracy; this procedure is much more complicated than the quantitative determination of arsenic in the state of sulphide.

Arsenic is separated from lead, mercury, silver, bismuth, cadmium, and copper, by digesting the mixed sulphides in an excess of sulphide of ammonium, which dissolves the sulphide of arsenic. The solution is subsequently filtered off, and the sulphide of arsenic thrown down from the filtrate by addition of a slight excess of hydrochloric acid; and on the deposited sulphide being refiltered, washed, dried, and treated as in the foregoing process, the amount of arsenic is found. Antimony and tin are most difficult of separation from this metal.

ROSÉ recommends the following for separating antimony from arsenic:—The alloy is heated to redness in an atmosphere of hydrogen gas, in an apparatus similar to Fig. 128, represented at page 211. When the quantity of arsenic is considerable, it is necessary that the diameter of the tube, soldered to the further side of the glass bulb containing the alloy, be not too small.

As soon as the apparatus is filled with hydrogen gas, heat is applied to the bulb, and is continued until no more metallic arsenic is deposited in the end tube. By means of a small spirit-lamp, the metal is constantly expelled from the tube, leaving it clear.

When the arsenic has been completely eliminated from the tube, the glass bulb is suffered to cool, but without interrupting the current of hydrogen. It is then weighed with the residuum of metallic antimony, and the loss indicates the quantity of arsenic. It is necessary in this operation not to employ too strong a heat, which would slightly volatilize the antimony. It is scarcely necessary to add, that the operator should take great care not to inhale the arsenical vapors, on which account the experiment must not be conducted in the laboratory, but under the hood of the furnace opening into the chimney-flue. Nearly all the arsenic found in nature, under the name of *native arsenic*, contains small quantities of antimony, which may be determined by the previous method.

When, however, antimony and arsenic exist in solution, or when the two metals being combined in the solid state are united with other substances, so that the method which has just been described cannot be employed, another process must be adopted to separate them from each other. The solution is diluted with a sufficient quantity of water, after having added tartaric acid thereto, without which precaution the addition of water would render it milky.

If the combination under examination consists of metals in the reguline state, it is dissolved in aqua regia, tartaric acid is poured into the solution, and water is then added. A current of sulphide of hydrogen is next passed through the liquor to saturation; it is then very gently heated, in order that the metallic sulphide may settle completely. When the solution contains arsenic acid, it may be easily perceived that the first precipitate formed is sulphide of antimony, and it is only after some time that the sulphide of arsenic falls down, so that at first a layer of an orange-red color is deposited, which is covered afterwards by another layer of a light, yellow color. It is therefore necessary, before filtering, to mix these two layers well together by stirring with a glass rod. The whole is then filtered through a weighed filter, upon which the sulphides are dried at an extremely gentle heat until their weight remains constant. After having determined the weight of these sulphides, a portion—about half of it—is shaken down into a glass, the remainder is very gently heated again with the filter, and the whole is weighed for the purpose of ascertaining the weight of the portion about to be operated upon. The portion in the glass is to be treated very cautiously with aqua regia till the sulphides are oxidized.

Tartaric acid is then added to the solution, which is to be diluted with water. If any sulphur has separated, it must be filtered from the liquor, and its quantity ascertained. Chloride of barium is now poured into the filtrate, to precipitate the sulphuric acid which has been formed. From the weight of sulphate of baryta, that of the sulphur which it contains is calculated, and the portion of sulphur which has not been oxidized by the aqua regia is added to the quantity previously determined. The whole of the sulphur contained in a given weight of metallic sulphide having thus been determined, it is easy to deduce therefrom the collective weight of the antimony and arsenic.

The quantity of antimony is determined in another portion of the mixed sulphides, in the same manner as directed for that metal in the preceding page. When the amount of antimony and sulphur are known, the arsenic is easily found by deducting the united weights of those two bodies from the quantity of the mixed sulphides taken; the difference is the weight of the arsenic.

LEVOL estimates the arsenic which may be alloyed with copper and tin in bronzes, as follows:—Having dissolved the compound in hydrochloric acid and evaporated to dryness, nitric acid is added, and the whole heated, which renders the tin, in the form of binoxide or stannic acid, insoluble, and the arsenious acid partially remains with it. The precipitate is dried and reduced by hydrogen gas. The reduction takes place at a dull red heat, the greater part of the arsenic being separated by sublimation; a small quantity still remains with the tin, but this is removed by treating the alloy with hydrochloric acid, which dissolves the tin, leaving the other constituent undissolved. The compound may also be acted upon by zinc and sulphuric or hydrochloric acid, by which treatment the whole of the arsenic is removed in the form of gaseous terhydride, from which the metal may be abstracted, and its quantity estimated by transmitting the gas through a solution of protoxide of tin, of known strength, at a slightly elevated temperature—the arsenic is taken up by the tin, and may be found by the increase of the weight of the latter. A solution of tin in cold weak nitric acid, appeared to LEVOL to be the most effectual for collecting the arsenic; the soluble protosalt thus formed readily comes in contact with the molecules of the arsenic, and when the temperature of the liquid is raised to convert the protoxide of tin into peroxide, the latter seizes on the arsenic and carries it down as it precipitates.

If arsenious and arsenic acids are present, they may be thus determined. The solution of the two acids is divided into equal parts; one part is treated with a stream of sulphide of hydrogen, and the second portion reserved for further operations. The sulphide of arsenic which falls is collected, dried at 212° Fahr., and weighed, after which the amount of sulphur is determined as before specified.

A solution of indigo, together with a quantity of hydrochloric acid, is poured into the second portion; a weighed quantity of hypochlorite of lime is next taken, and dissolved in a definite measure of tepid distilled water, and the solution subsequently dropped from a burette into the arsenical colored liquid, till the blue of the indigo disappears. By knowing the weight or volume, together with the strength, of the liquid employed, the chlorine required to effect the oxidation of the arsenious acid is calculated. The principle of the decomposition of the hypochlorite of lime by the hydrochloric acid, is the annexed:—

$$\underbrace{Ca \begin{Bmatrix} Cl \\ O \end{Bmatrix}}_{\text{Hypochlorite of lime.}} + \underbrace{H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{Cl}_{\text{Chlorine.}} + \underbrace{Ca\,Cl + H\,O}_{\text{Chloride of calcium and water.}}$$

Or,

$$\underbrace{Ca\,Cl, Ca\,O, Cl\,O}_{\text{Hypochlorite of lime.}} + \underbrace{2\,H\,Cl}_{\text{Hydrochloric acid.}} = \underbrace{2\,Ca\,Cl}_{\text{Chloride of calcium.}} + \underbrace{2\,H\,O}_{\text{Water.}} + \underbrace{2\,Cl}_{\text{Chlorine.}}$$

And the oxidation of the arsenious acid by the liberated chlorine is shown in the following equation:—

$$\underbrace{As\,O_3}_{\text{Arsenious acid.}} + \underbrace{2\,Cl}_{\text{Chlorine.}} + \underbrace{2\,H\,O}_{\text{Water.}} = \underbrace{As\,O_5}_{\text{Arsenic acid.}} + \underbrace{2\,H\,Cl}_{\text{Hydrochloric acid.}}$$

On calculating the quantity of arsenious acid found, and deducting it from the total weight of arsenic indirectly ascertained by the foregoing analysis, the difference in weight is the arsenic present in the form of arsenic acid.

BALSAMS.—*Baumes*, French; *balsame*, German.—This term was formerly applied to all liquid vegetal resins, as well as to a great number of pharmaceutical preparations. To avoid confusion, the French chemists confine the term balsam to vegetal substances composed of benzoic acid with more or less volatile oil. But as this would exclude copaiba and some other substances, popularly called balsams, most of the German chemists retain the old acceptation, and divide balsams into those which do not, and those which do, contain that acid. To the former, which are also called oleo-resins, liquid resins, terebinthinates, belong the different turpentines, including Canada balsam, copaiba, and opobalsamum, or Mecca balsam: they are semi-liquid, resinous, or glutinous juices, which flow spontaneously, or by incisions, from various vegetals, especially those belonging to the orders Coniferæ, Terebinthaceæ, and Leguminosæ. They have a hot and acrid taste, and a strong odor, which, in some, is very fragrant, in others less agreeable, but peculiar. They consist of a volatile oil and resin. Their odor. their semi-liquidity, and most of their medicinal activity, are owing to the oil which they contain; this may be procured from them by distillation, and volatilizes by exposure to air, whereby they become hard. From the next, or true balsams, they may be readily distinguished by not yielding benzoic acid. Those balsams which contain benzoic acid, or balsams properly so called, are solid, soft, or liquid substances, according to the quantity of volatile oil in their composition; they have an aromatic, usually agreeable odor, and a warm acrid taste. They dissolve in alcohol, and the solution, when mixed with water, becomes milky, owing to the precipitation of resin. By sublimation, as well as by other methods, they afford benzoic acid, from which they derive their physical effects. They are procured chiefly from the orders Styraceæ, Leguminosæ, and Balsamaceæ. To this class belong benzoin, styrax or storax, Tolu and Peru balsam, dragon's-blood, and liquidambar.

The class of bodies comprehended under the general name of balsams, has not been forgotten in that active investigation of organic bodies to which several chemists have, with peculiar predilection, devoted themselves, especially since the discovery of easier and more certain methods of research, than those formerly known, have removed the chief difficulties.

A strict examination of the substances has been necessary, as the knowledge of them given in scientific works did not correspond with the advanced state of chemistry. In former times, the analyses of the balsams were purely qualitative; everything crystalline, and which united with a base, was considered as benzoic acid; those which did not enter into union were described as camphor. If, on distillation, a volatile fluid passed over, it was deemed sufficient to state that the substance contained also a volatile oil. In the present advanced state of analysis, greater precision is required, and every constituent of a compound is submitted to careful investigation.

CANADA BALSAM.—This is a turpentine from the balm of Gilead fir—*abies balsamea.* It is slightly yellow, transparent, possesses an agreeable terebinthic odor, and an acrid taste. When fresh, it flows readily, but in time solidifies. BONASTRE analysed this balsam, and found the following:—

	Centesimally represented.
Essential oil,	18·600
Resin, soluble in alcohol,	40·000
Resin, difficultly soluble,	33·400
Elastic resin,	4·000
Bitter extractive and salts,	4·000
	100·000

COPAIBA BALSAM is obtained from incisions made in the trunk of the *Copaifera officinalis,* a tree which grows in the Brazils and Cayenne. It is of a light yellow color, rather liquid, transparent; has a bitter, sharp, burning taste, a suffocating and unpleasant smell; specific gravity 0·950 to 0·996; soluble in absolute alcohol, partially dissolved by spirit of wine, and gives, with alkalies, crystalline compounds. It dissolves with the aid of a gentle heat one-fourth its weight of carbonate of magnesia, and remains translucent. The analysis yields the annexed:—

	Centesimally represented.
Volatile oil,	38·00
Copaivic acid,	52·75
Brown soft resin,	1·66
Water and loss,	7·59
	100·00

The oil contains no oxygen, has a composition like oil of turpentine, and, according to DURAND, dissolves caoutchouc.

Copaiba balsam is used for making paper transparent, for certain lacquers, and in medicine. In the latter, PEREIRA preferred the oil to any preparation of the balsam. SIMON remarks that the genuineness of copaiba balsam is frequently tested by mixing three parts of it with one part of ammonia, specific gravity 0·96; if the mixture be rendered clear by agitation, the balsam is usually considered genuine; but if to this balsam the sixth part of oil of juniper be added, it behaves with ammonia precisely as if none of the juniper oil were present, which proves the insufficiency of the above test. The same chemist further adds:—Of late there has frequently appeared in commerce, a balsam which will not at all bear the above test with ammonia; much trouble has been taken to detect any adulteration in this, but it is perfectly genuine. It contains from twenty to twenty-five per cent. more essential oil, which renders it more liquid, but the oils from both kinds of balsam are identical in odor, and in all other properties; the residuous resin in both kinds becomes equally hard and brittle, which entirely does away with the supposition of its having been sophisticated with any fat oil: the two resins, however, differ; the one affording a soapy combination with caustic alkalies, which the resin of the new balsam does not.

The different sorts of balsam of copaiba hitherto found in commerce, are characterized by the presence of an acid—copaivic acid—in consequence of which, if mixed in proper proportions with solutions of potassa or ammonia, they form therewith a more or less clear liquid, crystals of ammoniacal salt precipitating from the latter after some time. Hitherto, if this reaction did not take place, the balsam has been supposed to be adulterated with fixed oils, turpentine, *et cetera.*

Recently, however, as just observed, a balsam has been introduced into commerce which does not show this reaction, and is, notwithstanding, unadulterated. This kind was imported into London by one of the most respectable firms there, and was accompanied with the assurance that the article was not sophisticated, and came originally from the Brazils. The statement was supported by analysis, and the conclusion to be drawn therefrom is, that some species of Copaifera, or some allied genus, yields a balsam, greatly resembling the ordinary balsam of copaiba, and yet essentially differing from it in its nature.

The balsam in question is thinner, and of a lighter yellow color than the common kind, so that it is strikingly distinguished from the latter by this character. It possesses the disagreeable smell of the balsam of copaiba, and the peculiar persistent taste, in perfect purity. The specific gravity is 0·94. Mixed with solutions of potassa or ammonia, it remains in all proportions turbid, and never forms a saponaceous mixture with them; after some time it again separates from these liquids. In alcohol it does not perfectly dissolve, like the ordinary copaiba balsam, but forms with it a milky liquid. This originates from a resin contained in it, which does not dissolve in alcohol. It contains eighty-two per cent. of oil, and eighteen per cent. of resin.

In order to obtain the volatile oil in a pure state, the balsam was distilled with the addition of water. By this process, one part of oil and about thirty-two parts of water were obtained. The distilled oil was subjected to distillation with a fresh addition of water, and the oil thus procured, which was clear, was dried by chloride of calcium. It is thick, colorless, has a strong and pure copaiba smell, and an acrid, burning taste. Its specific gravity is 0·91; the boiling point is at 485° Fahr. The boiling oil readily becomes decomposed by the heat: it assumes a yellowish color, becomes viscid, then brown, thick, and glutinous, and at last is perfectly decomposed, whilst carbon is separated; hence the specific gravity of the vapor could not be determined. With ether it can be mixed in all proportions, but not so with absolute alcohol, of which a rather large quantity is required for its complete solution. In common alcohol it dissolves with great difficulty; if dry ammoniacal gas be passed into it, it rapidly absorbs it, and enters into combination, forming a reddish-brown fluid, which, if saturated, fumes in the air. Neither by leaving it at rest, nor by cooling it, could a crystallizable compound be obtained from this solution.

According to an analysis of this oil, it belongs to the carbide of hydrogen oils, being free from oxygen, and is composed after the general formula, $C_{10} H_8$. It is distinguished from ordinary oil of copaiba by its viscidity, by its behavior with alcohol and ammoniacal gas, and by its boiling point, and resembles it only in smell. It may be denominated *Paracopaiba oil.* Nitric acid, of 1·32 specific gravity, produces no reaction at common temperatures. If, however, it be heated, a violent reaction takes place, and the oil is converted into a resinous substance. If diluted nitric acid be employed, the mixture boils quietly, without coming over, and within a few days the oil dissolves perfectly in the liquid. At the same time, nitrous acid, carbonic acid, and volatile peculiar acids, are eliminated, which form, with acetate of lead, a precipitate, but which have not been further examined. The residue being evaporated, and diluted with water, yields an acid resin not affected by nitric acid, and a crystallizable acid, which remains in solution, whilst the former is precipitated. This resin is of a yellowish-red color, dissolves in some degree in boiling water, and forms again a milky precipitate when cold. In ether and alcohol it dissolves with facility, and from the spiritous solution small resinous crystals are afterwards precipitated. It has a strong acid reaction, and forms, with potassa or ammonia, red neutral compounds, which are soluble in water.

The acid which is obtained after the evaporated nitric acid solution of the oil has been freed from the resin just described, by the admixture of water, crystallizes in thin, transparent, colorless laminæ. It dissolves easily in water, spirit of wine, ether, and petroleum, is inodorous and bitter, and has a slight acid reaction. Although a great quantity of volatile oil had been employed, only a small quantity of acid was obtained, which was not sufficient for further experiments.

Fuming nitric acid detonates with the paracopaiba oil without the application of heat; iodine, however, is dissolved by it, without effecting any brisk reaction. Chlorine produces a violent disturbance, hydrochloric acid vapor escapes, and the mass becomes yellow and viscid; strong sulphuric acid induces a deep violet color.

The difference between the resins of the two sorts of balsam of copaiba is still greater than that between the volatile oils.

In order to obtain the resins in a pure state, the balsams—freed by distillation with water from the greater part of the volatile oil—were further boiled with water, till at last every trace of smell had disappeared. A light-brown brittle substance remained, which consisted of two distinct resins, but both absolutely indifferent. They can easily be separated from one another by alcohol, in which one dissolves with great facility, whilst the other is scarcely soluble, even when the alcohol is absolute and hot.

The resin soluble in alcohol constitutes the greater proportion, and can be obtained in a pure state by repeated solution in this menstruum; the other resin wholly remains behind. The former is of a light-yellow color, not friable in the cold, softens at a gentle heat, and is decomposed if the temperature be slightly increased; at the same time it assumes a deeper color, and becomes a viscid fluid. In weak boiling spirit it dissolves, but precipitates again for the most part in the cold, in the form of white flakes. In concentrated alcohol it readily dissolves also in the cold; equally so in ether and petroleum. The alcoholic solution has no acid reaction, and if left at rest the resin precipitates, in proportion as the alcohol evaporates, in small drops which betray no trace of a crystalline texture. With acetate of copper no precipitate is formed; in solutions of potassa or ammonia it does not dissolve.

Two analyses gave the annexed results:—

	Centesimally represented.	
Carbon,	59·98	60·06
Hydrogen,	8·48	8·27
Oxygen,	31·54	31·67
	100·00	100·00

The resin insoluble in alcohol remains after the preparation of the first. It should be boiled again several times in absolute alcohol, in order to obtain it perfectly pure. During this process its quantity considerably diminishes; it is then to be dissolved in ether, and the solution filtered and heated for some time on the water-bath, in order to expel the last traces of solvent.

It possesses the same color as the first, does not dissolve in dilute alcohol, is soluble only with difficulty in boiling absolute alcohol, and when cold, again precipitates for the most part from this solution. In ether and petroleum it readily dissolves. The solution has not an acid reaction, and no crystals could be obtained from it. In a solution of potassa or ammonia it is perfectly insoluble; if boiled with it, it forms a milky turbid mixture; the resin, however, precipitates again, perfectly, when at rest. With acetate of copper, a slight precipitate is formed. It melts with difficulty.

The elementary analyses of two samples prepared in different ways, gave the following:—

	Composition per cent.	
Carbon,	81·76	82·12
Hydrogen,	10·56	10·48
Oxygen,	7·68	7·40
	100·00	100·00

The analyses were performed with oxide of copper and chlorate of potassa, for without the addition of the latter no perfect combustion could be effected.

OPOBALSAM.—Balm of Gilead—Mecca Balsam.—This is a whitish, turbid liquid, flowing from incisions made in the *Balsamodendron Opobalsamum*, or Beshan of Arabia. It is very odorous, and on exposure resinifies. The analysis gives

	Centesimally.
Volatile oil,	30·00
Soft resin, insoluble in alcohol,	4·00
Hard resin, soluble in alcohol,	64·00
Extractive,	0·40
Loss,	1·60
	100·00

Its physiological effects are believed to be similar to those of balsam of copaiba and the liquid turpentines.

It is never employed by Europeans, but the Asiatics use it for its odoriferous as well as its medicinal qualities, and they have ascribed to it the most wonderful properties.

BENZOIN, OR GUM BENJAMIN.—*Benzoin*, French; *Benzöe*, German.—Benzoin is improperly called a gum, as it ranks among balsams. It is a species of resin, and is used chiefly in perfumery. It is extracted by incision from the trunk and branches of the *Styrax benzoin*, or *Lithocarpus benzoin*, which grows in Java, Sumatra, and in the kingdom of Siam. The plant belongs to the Decandria monogynia of LINNÆUS, and the natural family of the Ebenaceæ. The bark of the six year old tree is slit to allow a liquid to flow out, which concretes by exposure to the sun and air, and is imported in brittle masses, the fracture of which presents a mixture of red, brown, and white grains of various sizes; when white, and of a certain shape, they are called *amygdaloid*, from their resemblance to almonds. The *sorted* benzoin is, on the other hand, very impure.

Its fracture is conchoidal, and its lustre greasy: its specific gravity varies from 1·063 to 1·092. The smell is agreeable, somewhat like vanilla, which is most manifest when it is ground. It enters into fusion at a gentle heat, and then exhales a white smoke, which may be condensed into the acicular crystals of benzoic acid, of which it contains eighteen parts in the hundred. The following is a good process for extracting the acid: The resin is to be dissolved in three parts of alcohol, the menstruum introduced into a retort, and a solution of carbonate of soda dissolved in dilute alcohol gradually added to it, till the free acid be neutralised; then a bulk of water, equal to double the weight of the benzoin, is to be poured in. The alcohol being drawn off by distillation, the remaining liquor contains the acid, and the resin floating upon it may be skimmed off and washed, when its weight will be found to amount to about eighty per cent. of the raw material. The benzoin contains traces of a volatile oil, and a substance soluble in water, at least through the agency of carbonate of potassa. Ether does not dissolve benzoin completely. The fat and volatile oils dissolve very little.

The benzoin of Siam, which has been recently introduced into commerce, consists of agglutinated, broad, laminar pieces, and does not essentially differ from the preceding. From some experiments which WACKENRODER has made with it, five per cent. of benzoic acid might be extracted from it by treatment with carbonate of soda; and the residue afforded, on being boiled with hydrate of lime and much water, four per cent. more of pure benzoic acid. There is, therefore, a difference between this benzoin and the other kinds previously known, in the amount of acid.

The several sorts of benzoin met with may be conveniently arranged under two heads, *videlicet*—*Siam benzoin* and *Sumatra benzoin*. PEREIRA states that Siam benzoin is brought to England, either direct from Siam, or indirectly, by way of Singapore. It includes the best commercial sorts, or those known commercially as benzoin of the finest quality. It occurs in tears, in irregular lumps, and in cubical blocks; but, unlike the Sumatra, it never comes over enveloped in calico. It is in general distinguished from the other kinds by its warmer or richer tints. The dealers distinguish five or six qualities, the three best sorts being included under the name of *yellow Siam benzoin*, and the two or three inferior kinds being called *red* or *brown Siam benzoin*. The designations yellow, red, or brown, are used according to the tint of the resin by which the tears are agglutinated; but this division is altogether arbitrary, the colors passing indefinitely into one another.

SIAM BENZOIN IN TEARS.—*Benzoinum Siamense in lachrymis*, Latin; *yellow benzoin in the tear.*—This kind seems to be identical with the *true benzoin in tears*, which SAVARY says was brought in considerable quantity to Paris by the attendants of the Siamese ambassadors. It consists of irregular flattened pieces, some of which are angular, and the largest of them barely exceeding an inch in length. Externally, these pieces are shiny or dusty from their mutual friction, and are of an amber or reddish-yellow color; they are brittle, and may be easily rubbed to powder. Internally, they are translucent or milky, and frequently striped; they have a pleasant odor, but little or no taste. There is an inferior sort in tears, which consists of loose drops, mixed with pieces of wood and other impurities. It is worth only one-fourth of the price of clean good-sized tears, or clean lump.

SIAM OR LUMP BENZOIN.—*Benzoinum Siamense in massis*, Latin.—The finest kind consists of agglutinated tears, *white or yellow lump benzoin.* More commonly the tears are connected together by a brown resiniform mass, which, when broken, presents an amygdaloid appearance, from the white tears embedded in the mass—*amygdaloid benzoin.*

Inferior sorts of lump benzoin are reddish—*red lump benzoin.*

TRANSLUCENT BENZOIN.—Dr. ROYLE furnished Dr. PEREIRA with a sample of Siam benzoin, with properties somewhat different from the preceding. The small masses consisted of agglomerated tears, which, instead of being white and opaque, were translucent, or, in a few instances, almost transparent.

SUMATRA BENZOIN.—*Benzoinum ex Sumatra*, Latin. Though placed here second, this sort is the more important, being in many countries the only kind known. It is rarely imported directly from Sumatra, but, in general, indirectly by way of Singapore or Bombay, and now and then from Calcutta. Hence it is sometimes called Calcutta benzoin, though this port is out of the usual course.

It occurs in large rectangular blocks, marked with the impression of a mat, and covered with white cotton cloth. When broken, but few large white tears can be observed in it. The mass is principally made up of a brown resiniform matter, with numerous white small pieces of chips intermixed, which give to the broken surface a speckled appearance, like that of a fine-grained granite.

WACKENRODER obtained nine per cent. of benzoic acid from the benzoin of Siam.

The qualities of Sumatra benzoin are distinguished as *firsts*, *seconds*, and *thirds*.

The first sort occurs very seldom, and only by single chests, for which £50 or more the hundredweight are paid, for the Russian market.

The second sort is marbly, but not so white; and is also mostly taken for the Russian market, at £20 to £30 the hundredweight. Thirty chests of this sort, perhaps, are seen before one of the first quality is met with.

The third sort is browner, and less or not at all marbly. It fetches from £9 to £15 per hundredweight, and forms the usual commercial quality. Five times as much of this are met with as of all the other sorts put together.

There is a very inferior sort of benzoin—*inferior Bombay benzoin*—which invariably comes by way of Bombay. If it be the produce of Sumatra, it is remarkable that it never comes by way of Singapore.

Benzoin is sometimes imported into England direct from Siam and Sumatra; but usually indirectly from Singapore, Bombay, Penang, Calcutta, Madras, Batavia, *et cetera.* The greater part is re-exported for use in the ceremonies of the Greek and Catholic Churches. In 1839 only one hundred and eight hundredweight paid duty.

This balsam has repeatedly been the subject of chemical analysis. It was analyzed in 1811 by BUCHOLZ, in 1816 by JOHN, in 1823 by STOLTZE, and in 1845 by KOPP. It has also been examined by BRANDE, UNVERDORBEN, and others:—

	Bucholz.	John.	Stoltze.		
			White.	Amygdaloid.	Brown.
Volatile oil, aroma,	—	—	traces	traces	traces
Benzoic acid,	12·5	12·0	19·80	19·42	19·70
Resin { yellow, soluble in ether,	83·3	84·5	79·83	27·10	8·80
Resin { brown, insoluble in ether,			0·25	50·53	69·73
Matter like balsam of Peru,	1·7	—	—	—	—
Aromatic extract,	0·5	0·50	—	0·25	0·15
Ligneous matter and other impurities,	2·0	2·00	—	2·60	1·45
Water and loss,	—	0·25	0·12	0·10	0·17
Salts, benzoates, and phosphates,	—	0·75	—	—	—
Benzoin,	100·0	100·00	100·00	100·00	100·00

Benzoin, in its physiological effects, is similar to the other balsams; it is therefore used with advantage in chronic pulmonary catarrhs.

UNVERDORBEN found in benzoin, besides benzoic acid, no less than three different kinds of resin; none of which has, however, been turned to any use in the arts Annexed are his results:—

	Centesimally represented.	
Benzoic acid,	14·5	14·0
Resin, soluble in ether,	48·0	52·0
Resin, soluble in alcohol only,	28·0	25·0
Resin, soluble in carbonate of soda,	3·5	3·0
Brown resin, deposited by ether,	0·5	0·8
Impurities,	5·5	5·2
	100·0	100·0

According to KOPP'S researches, benzoin resin, subjected to distillation, is resolved into carbon, carbide of hydrogen, water, carbolic and benzoic acids. Thus, four equivalents of the resin—$C_{20} H_{11} O_4 = C_{80} H_{44} O_{18}$—produce—

3 Eqs. benzoic acid,	C_{42}	H_{18}	O_{12}
1 Eq. carbolic acid,	C_{12}	H_6	O_2
8 Eqs. carbon,	C_8		
2 Eqs. water,		H_2	O_2
18 Eqs. olefiant gas,	C_{18}	H_{18}	
	C_{80}	H_{44}	O_{18}

Benzoin is of great use in perfumery, as it enters into a number of preparations; among which may be mentioned fumigating pastilles and cloves, *poudre à la maréchale, et cetera.* The alcoholic tincture, mixed with water, forms *virginal* milk. It enters also into the composition of certain varnishes employed for snuff-boxes and walking-sticks, to give these articles an agreeable smell when they become heated in the hand. It is likewise added to the spiritous solution of isinglass, with which the best court-plaster is made.

The chief use of benzoin is in yielding benzoic acid; it forms a component of the incense burned during the ceremonies of the Roman Catholic Church, and contributes to the peculiar fragrancy of the perfume.

When the balsam is of the *best* quality, its fracture has the appearance of white marble; but this kind is seldom encountered. The value of this article may be judged of by the amount of benzoic acid it yields; when good, it ought to give fifteen or eighteen per cent.

STORAX BALSAM belongs to the same natural family as benzoin, being the product of *Styrax officinalis,* a handsome shrub, growing in the Levant, Palestine, Syria, and Greece, and cultivated in the Southern parts of Europe. The storax of commerce comes from Asiatic Turkey. The balsam exudes from incisions through the bark; and, when somewhat hardened, constitutes one or more of the balsamic substances known by druggists under the name of storax. The bodies thus denominated are very numerous, and of variable character and composition; they are for the most part artificial compounds, perfectly dissimilar from any of the genuine varieties. Real storax is extremely rare. It occurs, says BRANDE, in compact masses, of a very fragrant odor, and of a rich brown color, interspersed with white tears, whence the name *amygdaloid styrax.* It was formerly imported enveloped in a monocotyledonous leaf, under the name of cane or reed styrax—*styrax calamita.* In the drug market, two substances are generally met with bearing the name of storax; one of them is called *styrax liquidus;* it is usually of a black, brown, or grey color, and generally has a disagreeable odor, more resembling that of coal-tar than of the balsam. The other is usually labelled *styrax calamita,* and is a black, brown, or purplish article, either pulverulent or granular, or in the form of agglutinated lumps. Some of it is said to consist of pulverized decayed wood, imbued with a little liquid storax; other samples appear to be fine sawdust, impregnated either with coal-tar or something analogous, and not bearing the remotest similarity to the genuine balsam.

Simon first showed that the acid found in storax, and which had always been taken for benzoic acid, possessed all the properties of cinnamic acid; and an analysis of the silver salt by Marchand proved the acid to be the latter. Storax, as well as the tree producing it, was known to the ancient Greeks and Romans. It is alluded to by Hippocrates, Theophrastus, and Pliny.

Pereira states that he has met with two kinds of liquid storax in the shops; one is opaque, and the other pellucid. He thus describes them:—

Opaque Liquid Storax.—This is imported from Trieste in casks or barrels holding about four hundredweight each. It is opaque, of a grey color, has the consistence of birdlime, and the odor of storax, but frequently intermixed with a feeble smell of benzol or naphthalin.

The substance met with in the shops, and sold to perfumers under the name of strained storax—*styrax colatus*—is prepared from liquid storax, by heating it until the water with which it is usually mixed is evaporated, and then straining it. During the process, it evolves a very fragrant odor. The impurities are stones, sand, *et cetera*.

In consequence of Petiver's statement, storax has been supposed to be the produce of a species of *liquid ambar*. But several facts are unfavorable to this opinion:—Firstly: Its vanilla-like odor allies it to the products of *styrax officinale*, and at the same time separates it from all authentic products of the genus *liquidambar*. Dr. Wood, for example, found the genuine juice of *L. styraciflua* very different to that of liquid storax; and the fluid resin, called liquidambar, has no resemblance to it. Secondly: Marquart analyzed a specimen of the genuine resin of *L. altingia*, and obtained a volatile oil somewhat like styrol, and a substance similar to styracin; but their composition he found to be entirely different; for while styracin consists of $C_{24} H_{22} O_2$, the liquidambar resin was composed of $C_{16} H_{22} O_2$.

Pellucid Liquid Storax.—*Storax liquide pur*, Guibourt.—This substance was sold to Dr. Pereira under the name of *balsam* or *balsam storax;* and he was informed that it had been imported in jars, each holding fourteen pounds. It agrees with the *pure* or *fine liquid storax* of Hill, and the *styrax liquida finissima* of Alston. Professor Guibourt, to whom Dr. Pereira sent a sample, at first regarded it as balsam of liquidambar; but its odor has subsequently induced him to rank it among the products of *styrax officinale*. It is a pellucid liquid, having the consistence and tenacity of Venice turpentine, a brownish-yellow color, a sweetish storax or vanilla-like odor, entirely different from that of liquidambar. A few particles of bran or sawdust are intermixed with it. By keeping, it yields a white and acid sublimate on the sides of the bottle which contains it.

All the storax imported into this country comes from Trieste. The following are the results of Reinsch's analyses of styrax calamita:—

	1. Styrax calamita.	2. Brown granular.	3. Reddish compact.
Volatile oil,	?	0·5	0·4
Resin,	41·6	53·7	32·7
Subresin,	?	0·6	0·5
Benzoic acid,	2·4	1·1	2·6
Gum and extract,	14·0	9·3	7·9
Matter extracted by potassa,	15·0	9·6	23·9
Woody fibre,	22·0	20·2	27·0
Ammonia,	traces	stronger traces	strongest traces
Water,	5·0	5·0	5·0
Styrax calamita,	100·0	100·0	100·0

The volatile oil was obtained by digesting the distilled water of storax with ether. The *solid* oil was white, crystalline, and fusible; its odor was agreeable, its taste aromatic and warm. The *fluid* oil had not so penetrating an odor.

Simon found liquid storax to consist of styrol, cinnamic acid, styracin, a soft, and a hard resin.

Storax is used in medicine, and is called a stimulating expectorant. In its operation it is closely allied to balsam of Peru and benzoin, but it is less powerful than the latter. It is used also as a detergent in the form of ointment.

DRAGON'S-BLOOD.—This is a deep red resin, imported from the East Indies. The finest kind is in large red drops, and is said to be the produce of *calamus draco*. It also occurs in masses of various degrees of purity, and in sticks, enveloped in palm leaves; but, according to Brande, these varieties appear to be more or less sophisticated. The article when pure is of a dark blood color, soluble in alcohol and ether, and in alkalies. When this balsam is subjected to dry distillation, it fuses, yielding water, acetin, and three and a half per cent. of benzoic acid; as the temperature increases, carbonic oxide and carbonic acid are formed, and a reddish-brown oily fluid distils over, which is a mixture of several bodies. Glenard and Boudault isolated from this two carbides of hydrogen, which they named *dracyl* and *draconyl;* the former, the Editor, in conjunction with Hofmann, proved to be identical with *toluol;* and the latter, Blyth and Hofmann showed to be *metastyrol*.

LIQUIDAMBAR is obtained from the *liquidambar styraciflua*, a tree which grows in Mexico, Louisiana, and Virginia. Some specimens are thin, like oil, and others are thickish, like turpentine. It is transparent, amber-colored, has an agreeable and powerful smell, and an aromatic taste, which is somewhat pungent in the throat. Boiling alcohol dissolves it almost entirely. It contains a good deal of benzoic acid, some of which effloresces whenever the resin hardens with keeping.—*Ure*.

TOLU BALSAM is the produce of *Myrospermum toluiferum*, a tree growing on the mountains of Tolu and Turbaco, and on the banks of the Magdalena, between Garapatas and Monpox. It exudes during the heat of the day from incisions in the bark; and is imported chiefly by way of New York and Jamaica, generally in tin canisters, but sometimes in earthen crocks and in calabashes. On its arrival it is soft and tenacious, but gradually hardens; it is translucent, brown, very fragrant, and has a sweetish taste, softening between the teeth. When heated, it fuses and takes fire, diffusing an agreeable odor. Fremy states that the components of Tolu balsam are the same as those of the Peru balsam. These balsams only differ in their degree of organization, and especially in the facility with which the balsam of Tolu becomes resinified. The tree which yields the balsam of Tolu was formerly called *Toluifera balsamum.* Richard having carefully investigated the characters of the genus Toluifera, found that, with the exception of the fruit, they were identical with those of the genus now called *Myrospermum;* and as Ruiz states that the balsams of Tolu and Peru are obtained from the same tree, the *M. peruiferum* has been adopted by several writers, and by the London College, as the source of both balsams. Richard made a distinct species of the tree yielding the balsam of Tolu, and it is now called *M. Toluiferum.*

The Editor, some years ago, when distilling the balsam of Tolu, remarked the following:—There passes over at first aqueous vapor, and when the temperature is sufficiently elevated, a large quantity of benzoic, with a slight admixture of cinnamic acid, which solidifies immediately in the recipient into a white crystalline mass. When the fluid distilling over no longer solidifies, the receiver is changed; a yellow liquid condenses, which is a mixture of toluol and benzoic ether. The crystalline mass collected in the first receiver contains likewise a large quantity of the same liquid, which can be separated by mere distillation with water.

Balsam of Tolu is frequently adulterated with common resin. To detect this, pour sulphuric acid on the balsam, and heat the mixture, when it dissolves to a cherry-red fluid, without evolving sulphurous acid, but with the escape of benzoic or cinnamic acid, if no common resin is present; on the contrary, the balsam foams, blackens, and much sulphurous acid is set free, if it is thus adulterated.

PERU BALSAM.—As many readers of this work may feel deeply interested in the principal balsams, the Editor will give extracts from the excellent paper by Dr. Pereira, published in the *Pharmaceutical Journal*, on *Myrospermum Pubescens* and its medicinal products, *Balsamio*, balsam of Peru, and white balsam.

There is no article of the Materia Medica, the natural history of which is more obscure than that of the so-called Balsam of Peru; for in all the best modern pharmacological and botanical works, errors, confusion, and doubts, exist with respect to it.

Of the celebrated white balsam of America, European writers have little definite knowledge. It is mentioned, indeed, by most pharmacologists, but it is obvious from their statements that they are unacquainted with it; for some of them regard it as liquidambar, some as balsam of Tolu, and others as dry balsam of Peru; from all of which, as will be seen in the sequel, it essentially differs. Dr. Stenhouse undertook the chemical examination of the white balsam, the result of which led to the discovery of a new organic principle.

The balsam is quite neutral to test paper, and has a peculiar agreeable odor like melilot. When it is digested in ordinary spirit of wine, a considerable portion readily dissolves; and when the clear extract is allowed to repose for a day, it deposits a quantity of large white crystals. They retain a good deal of adhering resinous matter; but they can be obtained perfectly pure by digestion with a little animal charcoal and repeated crystallizations from hot alcohol. When pure, they are hard and brittle, colorless, tasteless, scentless, and form broad thin prisms, more than an inch in length. Insoluble in hot and cold water; but are readily dissolved by hot alcohol and ether. To these crystals Stenhouse has applied the name *Myroxocarpin*, the formula of which is $C_{43} H_{35} O_6$. It is a very indifferent substance, displaying no affinity for either acids or bases.

Historical Notice.—A brief historical survey of the most important works and papers relating to the balsams will make the reader fully comprehend the present state of knowledge with respect to these drugs, and the sources of the errors and obscurities which have hitherto encircled them.

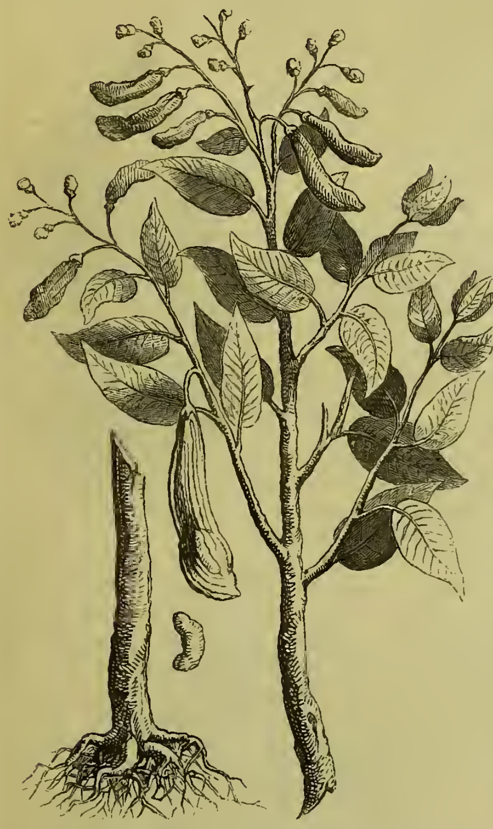
Nicolas Monardes, in whose work—the first edition of which was published at Seville in 1565—the earliest mention of Peru balsam occurs, calls it simply *balsamo*, and says that it is the produce of a tree growing in New Spain, and called by the Indians *xilo.* He describes the tree as being larger than the pomegranate, having leaves like those of nettles, and bearing a narrow, white, thin siliqua, or pod, of the length of a finger, and thickness of a sixpence, and which encloses at the end one bitter odorous seed, about the size of a pea. He mentions two modes of procuring the balsam—one by incision into the rind of the stem, the other by boiling the branches in water; and he afterwards notices its physical properties and valuable medicinal qualities.

Although Monardes was never in America, and must, therefore, have obtained his information from the reports of others, yet there is reason to believe his statements to be faithful.

The next writer who describes the balsam and the tree yielding it, is Francisco Hernandez, a Spanish physician and naturalist, who resided from the year 1593 to 1600 in Mexico and New Spain. He notices four balsam trees: one called *Hoitziloxitl*, a second termed *Iluaconex*, and a third denominated *Maripenda*, and the fourth found in the province of Tolu. Of these four, the first one appears to be identical with the tree which yields the so-called balsam of Peru, and a copy of Hernandez's drawing of it is therefore subjoined—Fig. 140.

Hernandez states that the Indian balsam tree—*arbor balsami Indici*—is called by the Mexicans *hoitziloxitl*, because it abounds in resin. He describes it as being of the size of a lemon tree, and having leaves which are larger than those of the almond, but rounder and more acuminate. The flowers are yellow, and are placed on the summits of the branches. The seeds are whitish, oblong, somewhat contorted, and lodged at the extremity of the oblong shells or fruits, which are longer and broader than the leaves. The tree, he says, is a native of warm regions, as Panuco, and was cultivated by the Mexican kings in the Hoaxtepec gardens. He gives two methods of obtaining the balsam, and states that the seeds yield, by pressure, an oil which resembles in flavor and odor that obtained from bitter almonds and peach kernels.

Fig. 140.



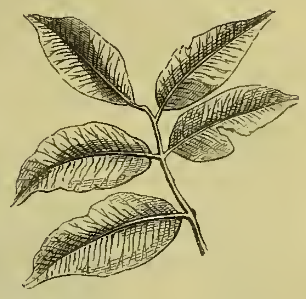
After the death of LINNÆUS, who had always been peculiarly anxious to ascertain the plant which yields this balsam, MUTIS sent to the younger LINNÆUS specimens of the leaves and flowers of a plant which, he said, grew in the warmest provinces of South America, and yielded Peruvian balsam. A description of this plant, to which the name of *Myroxylon peruiferum* was given, was published in the *Supplementum Plantarum.*

Annexed is a woodcut—Fig. 141—of the leaflets of *Myroxylon peruiferum.*

The figure is about one-third the natural size of the leaf. On the authority of MUTIS, many writers declare the above to be the source of balsam of Peru.

The first accurate botanical description of the tree which yields balsam of Peru, was given by RUIZ—in 1792—in his *Quinologia.* His memoir was translated into English by the late Mr. A. B. LAMBERT, and published by him in 1821, with a correct engraving of the plant, in his *Illustration of the Genus Cinchona.* RUIZ says the tree is known in Peru under the name of *Quinoquino*, and he calls it Myroxylon peruiferum, considering it to be identical with the *M. peruiferum* sent by MUTIS to the younger LINNÆUS. This, however, would appear to be an error, RUIZ's plant being, according to KUNTH and DE CANDOLLE, a distinct species from that of MUTIS. RUIZ states that the tree grows in the mountains of Panatahuas, in the forests of Puzuzu, Muna, Cuchero, Paxatin, Pampahermosa, and in many other countries near the river Maranon, in low, warm, and sunny situations; but the Indians of these places do not collect the balsam.

Fig. 141.



RUIZ says the balsam of Quinoquino is procured from incisions made in the tree at the beginning of spring, when the showers are gentle, frequent, and short; it is collected in bottles, where it keeps liquid for some years, in which state it is called *white liquid balsam.* When the natives deposit this liquid in mats or calabashes, which is commonly done in Carthagena and in the mountains of Tolu, after some time it condenses and hardens into resin, and is then denominated *dry white balsam*, or *balsam of Tolu*, by which name it is known in druggists' shops.

Dr. PEREIRA had two authenticated balsamic substances obtained from this tree: one procured from the stem by incision, and known in commerce as balsam of Peru, the other obtained by expression from the pericarp, and called *white balsam;* but the latter in no way resembles the balsam of Tolu of European commerce, and can scarcely be the white balsam alluded to by RUIZ. Mr. SKINNER—whose firm, KLÉE, SKINNER, and Co., Guatemala, largely exports balsam of Peru to Europe—never heard of any other balsam obtained from this tree. It is remarkable, however, that Mr. KLÉE speaks of the white balsam as being *balsam of Tolu.*

In 1823 appeared the sixth volume of HUMBOLDT, BONPLAND, and KUNTH's *Nova Genera et Species Plantarum.* In this work the plant of RUIZ and LAMBERT, called by RUIZ *M. peruiferum*, LINNÆUS, is denominated *Myroxylum pubescens*, and the designation *Myroxylum peruiferum* is retained for the plant sent by MUTIS to LINNÆUS. These distinctions have been adopted by DE CANDOLLE, who, however, has substituted JACQUIN's designation of the genus *Myrospermum* for *Myroxylon* or *Myroxylum.* But it is most unfortunate that the specific name *peruiferum* should be retained for a plant which does not yield the so-called Peruvian balsam.

In 1834, M. BAZIRE, a French merchant, who lived for many years in Central America, informed GUIBOURT that the so-called balsam of Peru was not the produce of Peru, but of the coast near Sonsonate. He also gave him some of the fruit of the tree which yields the balsam; but which, being deprived of its membranous wings, **Guibourt** failed to recognise as the fruit of *M. pubescens—M. peruiferum* of **Ruiz** and **Lambert**—and he therefore inferred that it was the produce of a different species. More recently, however, he has expressed an opinion that it is the fruit of the *Myroxylon peruiferum*, **Linnæus**. But on this point he has fallen into an error, the fruit being that of *Myrospermum pubescens* of **De Candolle**.

It may be here observed that M. **Bazire's** account is quite accurate.

Such was the state of uncertainty which existed on this subject, when Mr. **Skinner** undertook to clear up the mystery, by procuring for Dr. **Pereira** specimens of the tree and balsams from Central America, and by furnishing him with much valuable written and verbal information. By him the following facts were elicited:—

Firstly, That the tree which yields the so-called balsam of Peru and the white balsam, is the species described and figured by **Ruiz** and **Lambert**, *Myrospermum pubescens*, **De Candolle**.

Secondly, That *black balsam—balsam of Peru of commerce*—is obtained by incision from the stem.

Thirdly, That the *white balsam* is procured from the fruit by pressure.

Fourthly, That commerce exclusively obtains both of these balsams from the so-called Balsam Coast in Central America.

Dr. **Pereira**, writing further on the *Myrospermum* of Sonsonate, from which balsam of Peru, white balsam, and balsamito, are obtained, believed the plant to be identical with that figured by **Lambert**, and which, according to both **Kunth** and **De Candolle**, is *M. pubescens.* A careful examination of the specimens in the British Museum, from which **Lambert's** figures were drawn, led him to doubt the identity of his plant either with the Sonsonate species, or with the *pubescens* of **Kunth** and **De Candolle**. For the present, therefore, the plant will be designated the *Myrospermum of Sonsonate.*

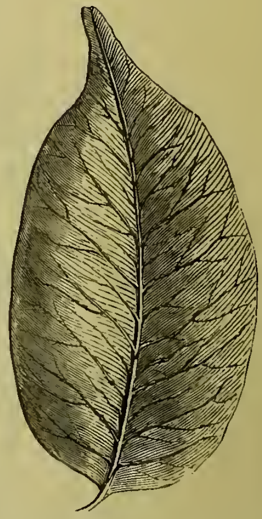
The specimens which Dr. **Pereira** received, consisted of branches, leaves, and fruits. The flowers were not met with.

The *branches* are terete, warty, but otherwise smooth, ash-colored, or ash-brown.

The *leaves* are alternate, petiolate, and imparipinnate. The common petioles appear to the naked eye devoid of hairs, but, when examined by the microscope, are found to be covered with a few short ones.

The *leaflets* are from five to eleven, alternate, with short petioles. Fig. 142 represents one of these leaflets in its natural size. Exclusive of foot-stalk, their length varies from about two to three and a half inches; and their greatest width, from one to one and a half inch. The most usual size is three inches in length, and one and a quarter to one and four-tenths of an inch in breadth. Their general shape is oblong or oval-oblong, in some cases ovate. They are round, or very slightly tapering, not cordiform at the base. Superiorly they contract abruptly into an emarginate point. To the naked eye, the partial petioles and mid-ribs appear devoid of capillæ, but when examined by the microscope, short lymphatic hairs, having a glossy or resinous appearance, are distinctly visible on them; and the partial petioles appear somewhat rough from transverse rugæ. The leaflets are elegantly marked by rounded and linear pellucid spots; the lines being usually parallel with, or in the direction of, the primary veins. To see the spots, the leaflets must be held up against a strong light, and examined by a magnifier.

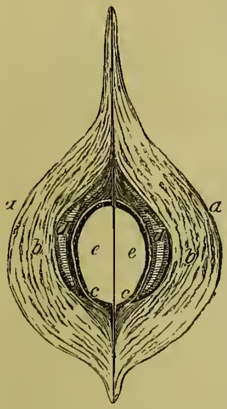
Fig. 142.



The *fruit* is a one-celled, one-seeded, winged, indehescent pod, called by some a samara, by others a samoroid legume. The fruit-stalk is naked at the base, but is amply winged superiorly. The fruit, including the winged foot-stalk, varies in length from about two to four inches; the usual length is three and an eighth, or three and a quarter. At the peduncular extremity, the fruit, or rather its winged foot-stalk, is rounded, or very slightly tapering, unequal sided; at the summit it is enlarged, turned, and rounded with a small point—the remains of the style—at the side. The mesocarp is fibrous; but immediately exterior to the endocarp, it contains, in receptacles, a yellow oleo-resinous or balsamic juice; which, by age, hardens and resinifies. **Ruiz**, **Kunth**, **Endlicher**, and **De Candolle**, describe this juice as immediately surrounding the seed, and being between it and the lining—endocarp—of the shell; but this is a mistake, it is exterior to the endocarp. The principal part of the balsam resides in the two receptacles or *vittæ*, one placed on either side; but if a transverse section of the fruit be examined by the microscope, numerous receptacles of the more or less dried balsam are perceived in all parts of the mesocarp. In the two larger receptacles, the balsam is usually found in the liquid state; but sometimes the walls of the receptacles are lined with the crystallized balsam—*myroxocarpin.* That the balsam resides in the mesocarp, and not in the cavity of the fruit, is proved by the cross section, which shows that the paries of the cavity of the fruit is continuous with the two sutures. The seed lies loose and dry in the cell of the pericarp, and is covered by a thin, white, membranous coat—testa. The cotyledons are yellowish and oily, have an agreeable odor, like that of the tonka-bean or melilot, and a bitter taste, somewhat resembling that of bitter almonds. By digesting the seeds in ether, a tincture is obtained, which yields, on evaporation, a very agreeable-smelling, amber-colored, soft extract, the odor of which resembles that of the cotyledons. Fig. 143 is a cross section of the fruit and seed—magnified:—*a a*, epicarp; *b b*, mesocarp; *c c*, endocarp; *d d*, large vittæ, or lacunæ, containing balsam; *e e*, cotyledons.

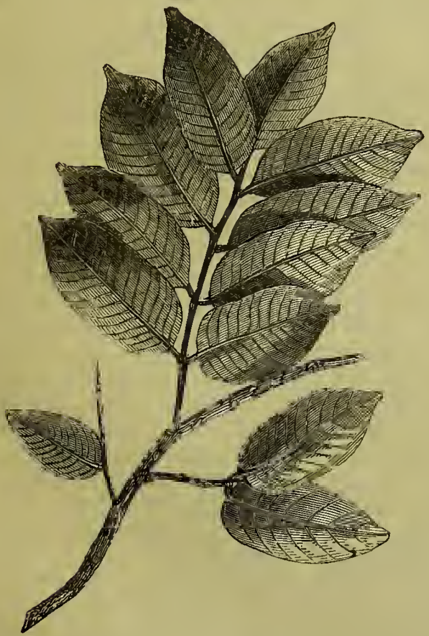
Some of the fruits given to Mr. Alfred Smee were sown by him in a pot, and placed in his hothouse. Several of them have produced thriving plants. A leaf of one of the plants thus raised, consists of five alternate leaflets, marked with pellucid dots and lines. To the naked eye, all parts of the leaves appear quite smooth; but when examined by the microscope, the general and partial petioles, the midribs, and the edges of the leaflets, are seen to be covered with small, reddish, appressed, lymphatic hairs. The lamina of the leaflets is emarginate, but the summit of the midrib, crowned by a small bush of hairs, projects, on the dorsal surface, beyond the lamina, and gives the appearance of a minute pointlet or mucro. As the leaflets dry, this pointlet appears to be shrinking and becoming brown. As the leaf grows, it probably falls off.

Fig. 143.



In the annexed sketches, Fig. 144 shows a leaf-bearing branch of the Myrospermum of Sonsonate, about one-third the natural size; Fig. 145, a fruit-bearing branch; Fig. 146, vertical section of the fruit; Fig. 147, lateral section of the fruit, showing the seed *in situ.*

Fig. 144.



The Myrospermum of Sonsonate so closely agrees in general with Pavon's *M. balsamiferum,* that Dr. Pereira was at first led to believe the two plants to be identical; and he was the more inclined to this opinion from the circumstance that, in one of the communications which he received from Sonsonate, the *Myrospermum* from that place was called *Myroxylon balsamiferum.*

Lambert's figure appears to have been made up from different specimens in Pavon's collection, and not from any one exclusively. Unfortunately, there is reason to suspect that the leaves of at least two species are contained in the collection under the same name, for in some of them the pellucid spots are exclusively round, in others round and linear. *Myroxylon balsamiferum,* Pavon; figured by Lambert as M. peruiferum, Linnæus. Fig. 148—*a*, flower, magnified; *b*, the curved ovary, surrounded at the base by the calyx.

Fig. 145.

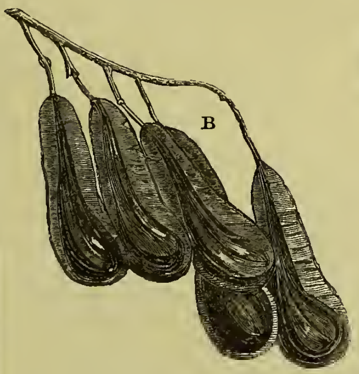
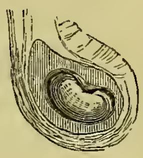


Fig. 147.



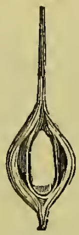
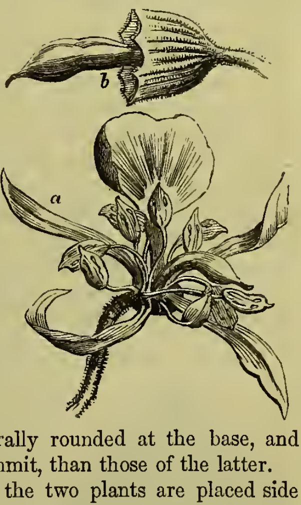


Fig. 146.

Firstly, *The size and shape of the leaves.*—Many of the leaves of Pavon's specimens—those which agree best with Lambert's figure—are larger than those of the Sonsonate plant. The shape also is different. While in the Sonsonate plant the prevailing shape is the oblong, that of Pavon's is more oval; again, the leaves of the former are more generally rounded at the base, and less tapering at the summit, than those of the latter.

Fig. 148.



When specimens of the two plants are placed side by side, the principal difference observed is the larger size and more tapering summits of the M. balsamiferum.

Secondly, *The size and shape of the fruit.*—The pods of Pavon's are longer than those of the Sonsonate plant. The average length of the latter rarely exceeds three or three and a quarter inches, while those of Pavon's specimen vary from four to six

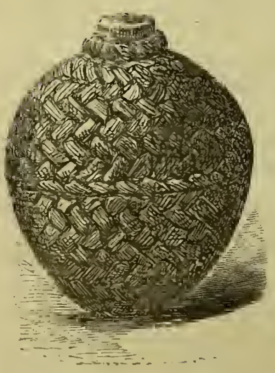
In the shape there is also a difference. In Pavon's plant the fruit is nearly of equal width, the two margins of the wings being parallel, or nearly so, throughout the greater part of the length of the pod. Thus, many of the pods are of the same breadth—about one and a quarter inch—for more than four inches of their length. In the Sonsonate specimens, on the other hand, the margins of the fruit diverge from each other in the direction from the peduncle towards the summit, and in no two parts has the pod the same width.

Central America is the country of the Myrospermum Sonsonate. It grows on the Balsam Coast—between 13° and 14° north latitude, and 89° and 90° west longitude—in the state of Salvador, where the black and white balsam are exclusively obtained from it. Hernandez gives Panuco as one of the places where it grows; and Clavigero states that it is common in the provinces of Panuco and Chiapan. Various medicinal products are obtained from the tree. By making an incision in the trunk of it, a liquor exudes called the *black balsam*, an admirable remedy for effecting the speedy cure of wounds of every description: from the flowers the *spirit of balsam* is made; the seeds or nuts produce the *oil of balsam*, an excellent anodyne; and the capsules yield the *white balsam*. From these simple kinds the *tincture* or *essence of balsam* is extracted. It is generally termed *balsamito*, and was a discovery of Don Jose Eustaquio de Leon, director of the mint in Guatemala, who published a description of the many virtues of this peculiar medicine. The only medicinal products of the tree are, black balsam—commonly called balsam of Peru—white balsam, and balsamito.

The *Sonsonate of St. Salvador; black balsam.*—This is the balsam of Peru of commerce—*Balsamum Peruvianum*, Latin. At Sonsonate it is termed *black balsam—balsamo nigro.* It is sometimes denominated the *black* or *liquid balsam* of Peru. Sonsonate or St. Salvador black balsam of commerce—balsam of Peru of the shops—is exclusively the produce of the Balsam Coast, which extends from the Ajacutla to the Port Libertad on the Pacific side of Central America.

The Sonsonate or St. Salvador *white balsam—balsamo blanco.*—This is often confounded with the balsam of Tolu. White balsam is obtained at Sonsonate by pressure, without heat, from the interior of the fruit and seed. It is imported in globular earthen jars, surrounded by a kind of plaited matting—Fig. 149—closed by an earthen stopper. The jar enclosed in the matting is about a foot high, and ten and a half inches in diameter, and contains about twenty pounds of balsam, which is partially concreted or crystallized on the sides. When removed from the jar, and put into a white glass bottle, it closely resembles, in appearance, strained American or Bordeaux turpentine. It is semi-fluid, or a soft solid, and by exposure becomes firmer. It is quite devoid of the fragrant cinnamon odor of the balsams of Peru and Tolu.

Fig. 149.



According to Mr. Skinner's account, obtained during his sojourn in Guatemala, the balsam was obtained thus:—A fire was made around, but at some little distance from the balsam tree; the bark was then cut, and a stick slipped in between it and the wood, so as to partially separate these two parts of the stem from each other. By working the stick about, somewhat in the manner of a pump-handle, the balsam, aided by the heat, exuded, and was absorbed by rags.

The only purification to which balsam of Peru is subjected in England, is one of a mechanical kind, that is to say, by standing, the balsam is allowed to separate from the water and any other impurities, and is then drawn off.

Mr. Saravia, of Sonsonate, having been requested to question the Indians respecting the production of balsam, replied:—The method used to extract the balsam from the trees, is to make several incisions, over which pieces of old cloth or rags are placed for the absorption of the juice; when they are well soaked, they are put in water to boil, until they have discharged the greatest part of the imbibed balsam. The liquid is then allowed to settle sufficiently, until the water rises, leaving the balsam at the bottom; next, the upper stratum is carefully poured off, and the balsam put into *tecomates*—gourds—although at this time it is not very pure. The rags are then put into *redes*—little bags of cords—which are strongly twisted to wring out any remaining balsam into the *tecomates.* When purchased, it is necessary to clean it again, because it still contains water and other impurities which some Indians will mix with it to gain greater weight.

The Black Balsam of Peru.— The method of obtaining black Peruvian balsam has always been a subject of controversy. When Stoltze, in the year 1824, published his *Treatise on the Black Peruvian Balsam*, he could not be convinced that it was obtained by a sort of *distillatio per descensum*, and not by decoction or spontaneous exudation, as he stated. Dr. Martius, of Erlangen, found his opinion corroborated by Dr. Pereira's; but that the balsam should, by boiling the rags in water, rise to the surface, and thus be removed, is impossible, for it has a specific gravity of from 1·150 to 1·160, and cannot, therefore, float on water in a state of ebullition. If a solution of common salt, that is to say, a liquid of greater specific gravity were employed, the balsam would then certainly float, but, at the same time, its agreeable odor would probably disappear, in consequence of the high temperature required for boiling the saline solution. As, moreover, the cinnamic acid contained in the black balsam is soluble in water, the greater portion of this acid would be given out to the liquid employed for the exhaustion of the rags. Now and then single drops of water, and sometimes even entire layers were supernatant *in the tin boxes, in which formerly the black Peruvian balsam was exported;* but this trifling portion of water Dr. Martius has always considered to be the product of *distillatio per descensum*, for he never found in it, by evaporation, anything but cinnamic acid, formerly regarded as benzoic acid. Moreover, whence arises in many of the tin boxes the sediment of several inches found in them after remaining at rest? Furthermore, what is the reason that the *tinctura balsami Peruviani* is sometimes of a lighter, and sometimes of a darker wine-yellow color, according as it is prepared from a lighter or darker colored balsam? This originates, no doubt, from the higher or lower degree of heat employed in the *distillatio per descensum.* Several years ago, a sort of black Peruvian balsam was in the market, which, on running down the glass, *appeared of a reddish-brown color,* was more fluid, and yielded, even after continued standing, a proportionately insignificant sediment. All this tends to show, that besides the various kinds of Myrospermum used for yielding the balsam, the higher or lower degree of heat employed in its preparation, must contribute to vary the quality obtained.

STOLTZE says he has never observed in his operations the products of a descending distillation, but there is a great difference between such a process and a gentle *distillatio per descensum.* Moreover, it must not be forgotten that the plants which yield the black Peruvian balsam, grow in a country which is in the highest degree favorable to the exudation of resinous juices from vegetals. Besides, the formation of cinnamic acid takes place, as it appears, only by the absorption of oxygen, or by an increased temperature.

As Bordeaux carries on a considerable trade in black Peruvian balsam, Dr. MARTIUS sought and received the following account from a friend there:—*Balsamum Peruvianum nigrum* is generally exported from Sonsonate and Ajacutla—Central America—in jars, and is mostly transferred to Europe in tin boxes, when it is at the same time deprived of water, mucilage, and salt, which is generally effected in a bathing tub. For some time past, the English have begun to take possession of this article, and import it from the eastern part of Central America, by way of Belise or Greytown. A captain, who formerly imported two hundred jars of balsam, saw them being filled, and was not a little astonished on finding here that water had separated during the voyage. In a fresh state the balsam is greenish and more fluid, than after having been kept for some time, when it flows with a golden-brown, and runs down the glass with a reddish color.

From the preceding communication it appears, firstly, that black Peruvian balsam, sold retail, has already undergone a purification; secondly, that the Peruvian balsam, as imported from America, contains water, mucilage, and salt; and thirdly, that the balsam in a fresh state is not only more fluid, but likewise possesses a greenish color.

The characters to be attended to in judging of its genuineness are, its pure odor, complete miscibility with alcohol, by which the absence of fixed oil is shown, and its suffering no diminution of volume after mixing with water, proving that there is no spirit present. A sign of its purity is, that one thousand parts of it should saturate seventy-five parts of crystallized carbonate of potassa.

Among the substances fraudulently mixed with Peru balsam, castor oil and copaiba balsam are the most difficult to discover. ULEX recommends the following method:—Ten drops of Peru balsam are mixed in a watch-glass with twenty drops of concentrated sulphuric acid, and then diluted with water. If the balsam is pure, a brittle resin is thus obtained; but when adulterated with castor oil and similar substances, this residue is proportionately soft. Sulphurous acid is likewise disengaged, which is not the case when the adulterating substance is copaiba.

Considerable variations in the specific gravity of Peru balsam must not be altogether overlooked. It usually varies between 1·14 and 1·16, but when sophisticated with as much as twenty-five per cent. of castor oil, it is much lower.

To detect copaiba balsam, the substance is to be heated in a small tube retort, until a few drops of a yellow oily liquid have passed over, which takes place at a temperature of 374° Fahr. This distillate is acid, and soon deposits crystals of cinnamic acid. If the balsam used was pure, it solidifies completely; but when adulterated with copaiba, the crystals float in copaiba oil. The distillate is then to be saturated with caustic potassa, and the solution of cinnamate removed by means of blotting-paper. The drops of oil which are then left, mix quietly with iodine if the balsam was pure, but cause a violent action in the presence of copaiba.

An expert chemist could tell the copaiba by its smell; in general, the purity and strength of the odor of the Peru balsam, and its perfect transparency, are certain proofs of its goodness.

SKINNER gives the method employed by the Indians of Central America for extracting the balsam from the tree. They begin by making an incision from two to two and one-third inches broad, and from three and a half to four in length; they then raise the bark from the living wood, and afterwards apply there pieces of cotton rags, after having heated the tree by surrounding it with a brisk fire for a short time. When they tap the tree for the first time, they make the incision rather more than a yard above the ground, and when the liquor ceases to ooze out, they make a second incision by the side of the first one, and in the same manner, but a little higher up; and thus they continue making new incisions as fast as they become exhausted around the tree. In the course of ten or twelve days, the rags become thoroughly impregnated with a thick olive-brown liquid; they are then withdrawn, and subjected to a fresh process. The rags saturated with the balsam are collected together and placed in an earthen vessel, called olla or pot, with some water, and boiled for five or six hours. During this operation the balsam detaches itself, and, so long as the boiling continues, mixes with the water; but as soon as the liquid becomes cold, the balsam, being much heavier, settles, and the water floats over it; hence it is easy to separate them from each other. Before the water cools, the cotton rags are removed; but as they still contain a certain quantity of liquid, they are subjected to a more forcible pressure by means of a small machine, made with pieces of wood, cords, and tourniquets. Lastly, they collect all the balsam extracted from these rags, after subjecting them to pressure for several days; pour off the water, and put the balsam, which has now become dark and liquid, into a calabash, for the purpose of carrying it to market. The balsam which flows from the tree always contains a considerable quantity of water, and hence the necessity of boiling this liquor after it has been extracted.

Annexed is **Stoltze's** analysis of the balsam of Peru:—

	Per cent.
Brown slightly soluble resin,	2·40
Brown resin,	20·70
Oil—cinnamein,	69·00
Benzoic and cinnamic acid,	6·40
Extract,	0·60
Loss and moisture,	0·90
	100·00

Balsamic Ethers.—**Scharling**, of Copenhagen, communicated to the Royal Danish Academy of Sciences a preliminary statement of some experiments made in order to produce ethers, by acting with potassa on various natural balsams. After having noticed the earlier investigations on Peruvian balsam, he observes that the formula given by **Fremy** for the composition of cinnamein, $C_{54}\,H_{26}\,O_8$, may be looked upon as $2\,C_{16}\,H_7\,O_2 + C_{22}\,H_{12}\,O_4$, of which the first member represents the formula for cinnamein given by **Plantamour**, and the second member that for cinnamic ether, which the latter chemist produced from Peruvian balsam. **Plantamour**, however, having used alcohol in his investigations, doubts might arise whether this had not occasioned the formation of the cinnamic ether. **Scharling** submitted one part of Peruvian balsam, and two or three parts of solution of potassa, of the specific gravity 1·3, to distillation, after the mixture had been left for twenty-four hours. The product consisted of water and two oily bodies, the one lighter, the other heavier than water. By drying and redistillation, the heavier liquid was obtained perfectly transparent, of high refractive power, of specific gravity 1·03, and with a boiling point of 401° Fahr. Immediately after the distillation, the smell was faint; but after having stood for a while, it became aromatic, like that of cinnamic ether.

Immersed in a refrigerating mixture of snow and rock salt, the whole remained liquid at 5° Fahr. The oily liquid, of less specific gravity, boiled at about 356°; its specific gravity was less than that of water; the smell not unlike aniseed; the taste sweetish, aromatic; cooled to 5° Fahr., the greater part congealed. Both these liquids are altered by distillation; for, even when heated in an oil-bath, they assume a light wax-yellow color before they begin to boil. As both these liquids thus offered great resemblance to cinnamic ether and peruvin, the same chemist tried to ascertain their identity with these substances, by treating them with hydrate of potassa and sulphide of carbon. Although the discoverer of xanthogenic acid, the late professor **Zeise**, remarks, that ether and sulphide of carbon, with hydrate of potassa, do not give xanthogenate of potassa; yet it was presumed that this salt might be produced by treating compound species of ether with hydrate of potassa and sulphide of carbon. As this supposition has been fully confirmed with different kinds of ether—for instance, with acetic ether—**Scharling** mixed separately both the liquids produced by Peruvian balsam with powdered hydrate of potassa and sulphide of carbon. In both these experiments the mixtures congealed; and when samples of the saline mass were dried between paper, and then dissolved in water, and tested with salts of copper and lead, they furnished yellow xanthogenate of copper and white xanthogenate of lead. Hence there can be no doubt that the liquid of higher specific gravity contains cinnamic ether, obtained for the first time without any addition of alcohol. By distilling the solution of potassa which had been separated from the cinnamein, only traces of an oily liquid were obtained; the rest of the distillate appeared to be water. Hence it is evident, that even at the ordinary temperature, and by the influence of a solution of potassa, the combination which at a suitable temperature is converted into a species of ether, is decomposed. By distilling Peruvian balsam with water, no oil or ether, as is known, is produced. Since this possibly might arise from the boiling point of cinnamic ether lying too high, the last named authority distilled a portion of Peruvian balsam with a solution of chloride of sodium, and a smaller portion with a concentrated solution of chloride of zinc. The last distillation was performed by dropping the balsam gradually into the boiling saline solution. By this process, besides water, some cinnamic acid and a very small quantity of two liquid, oily, brownish bodies, the one of greater and the other of less specific gravity than water, were obtained. Both had an empyreumatic odor; and, when boiled with water, a quantity of crystals of cinnamic acid were produced on cooling. No trace of cinnamic ether could be discovered in this distillate. By subjecting Peruvian balsam to dry distillation, several oily liquids were obtained, containing a great quantity of cinnamic acid, as also water. The former crystallized on cooling, and was collected on a filter; the liquid that had passed through, after it had been dried over chloride of calcium and redistilled, was treated with powdered hydrate of potassa and sulphide of carbon. No traces of xanthogenic acid could be detected in this mixture.

A portion of Peruvian balsam was next operated upon with a solution of carbonate of soda. The aqueous solution obtained behaved like a solution of cinnamate of soda. The remaining substance was exsiccated, dry carbonate of soda added to it, and the mixture subjected to destructive distillation. The distillate resembled in appearance the products from the dry distillation of the Peruvian balsam; but in this traces of xanthogenic acid were found by suitable treatment. From these experiments, therefore, it is not to be concluded *that cinnamic ether pre-exists in the balsam, but that it is most likely formed by the action of strong bases.*

Simon's investigation on liquid storax eliminated a body which he called *styracon.* He found that, on treating liquid storax in the same manner as he had treated Peruvian balsam, he immediately obtained a distillate, from which, after standing for a while, a body separated, possessing all the properties assigned by him to styracon. Moreover, it easily dissolved in alcohol of 0·851 specific gravity. By treating the styracon with powdered hydrate of potassa and sulphide of carbon, xanthogenate of potassa was formed amongst other products. Hence it is supposed that the styracon constitutes a compound ether. From want of styrol, he examined how benzol would act with hydrate of potassa and sulphide of carbon. No xanthogenate of potassa was produced. Balsam of copaiba was next treated with hydrate of potassa, and then distilled. A considerable quantity of oil, which floated on the distilled water, was immediately obtained. When the water had been poured back and distilled a second time, the quantity of oil collected constituted about five ounces, and the distilled water about twenty. A pound of balsam and a pound and a half of solution of potassa—specific gravity 1·25—had been used. The oil did not appear to differ from that of balsam of copaiba which occurs in trade; but on treating these oils with hydrate of potassa and sulphide of carbon, no formation of xanthogenate of potassa could be perceived. By treating Venetian turpentine in a similar manner, an oily liquid was obtained, which, when dried over chloride of calcium, or lime, did not appear to be acted upon by powdered hydrate of potassa. For several hours after the addition of the potassa, the color of the liquid remained unaltered, and exhibited no change of temperature. On adding sulphide of carbon, a white saline mass was formed after some time, which gradually caused the whole mixture to congeal into a jelly. After twenty-four hours this jelly was thrown upon a filter; and when the greater part of the liquid which the mass contained had run off, the residue was most carefully pressed between paper. A part of the product thus obtained was dissolved after being dried; another portion was shaken with ether, in order to remove all adherent oil and resin. The ether was separated by filtration, and the saline mass, after being dried, was likewise dissolved in water. Both these solutions immediately afforded brown precipitates with chloride of copper, but which after some time became yellow.

With nitrate of lead, whitish-yellow precipitates were produced; and with several other solutions of salts, reactions similar to those of xanthogenic acid were obtained, except that all the precipitates had in general a somewhat darker color. This circumstance led to the supposition that an ether had been formed by the action of the potassa on the Venetian turpentine. The boiling point of the distillate was about 307° Fahr.; its specific gravity 0·87°; the solubility in alcohol of 0·823° specific gravity, was identical with that of common oil of turpentine.

These properties agree so nearly with those of ordinary turpentine oil, that the supposition of the liquid being a species of ether was abandoned; whereas it was presumed, that if Venetian turpentine was distilled with water, the oil obtained would exhibit the same relations to hydrate of potassa and sulphide of carbon as the above-mentioned liquid. Experiment gave an affirmative conclusion. Common oil of turpentine, recently distilled and well freed from water, was treated as above, the results, upon the whole, were the same; consequently, it is possible to produce, by the action of hydrate of potassa and sulphide of carbon, from pure turpentine oil, a combination possessing great resemblance to xanthogenic acid. But, in order to form this substance, it is absolutely necessary to have well-fused hydrate of potassa; because, in the state in which it is often met with in commerce, it contains too much water. The whole of the turpentine oil cannot be decomposed by the sulphide of carbon and hydrate of potassa. The same appears to occur in this decomposition as in the production of terpin; a part only of the turpentine oil enters into the new combination.

Scharling observed, that though it is asserted that all pure turpentine oil consists only of $C_{10}\ H_8$, and that the boiling point and the specific gravity are alike, yet the oil from Venetian turpentine appears in several respects to differ from the oil of common turpentine. Thus the last-mentioned oil is speedily colored by the hydrate of potassa, which is not the case with the oil of Venetian turpentine. The latter oil polarizes the light to the left; but only a rotation of 25° is required to produce the violet color. The same is the case with a saturated solution of chloride of dadyl in alcohol, when the dadyl has been prepared from Venetian turpentine.

Common turpentine oil also polarizes the light to the left; but, to produce the violet shade, a rotation of 70° is required. This also happens both with a saturated alcoholic solution of chloride of dadyl prepared from common turpentine oil, and the liquid part of that turpentine oil from which the compound resembling xanthogenate of potassa had been produced. The longer the turpentine oil has been kept, the more strongly is it acted upon by the hydrate of potassa. It is owing to this circumstance that at times it produces an increase of temperature of more than 108° Fahr., then forms a clear brown gelatinous mass, which appears in a great measure to prevent the production of the compound resembling xanthogenate of potassa. Even when common turpentine, recently rectified and dried over lime, is employed for the preparation of this salt, a much darker product is generally obtained than with oil from Venetian turpentine. By allowing the saline mass, which in general contains potassa and sulphide of potassium, to remain exposed to the air, the substance becomes clearer, and the precipitate produced by sulphate of copper turns yellow much sooner.

The compound resembling xanthogenate of potassa from *terpin* has not yet been obtained; whether it can be procured from *terpinol* remains undecided.

Statement of the Imports and Exports of the different balsams, in pounds, at the ports of the United Kingdom, in the years 1849 and 1850:—

	1849.		1850.	
	Imported.	Exported.	Imported.	Exported.
Canada balsam,.......	6,912	—	19,038	15
Copaiba "	64,400	53,536	53,200	20,944
Peru "	993	1,196	13,743	3,787
Tolu "	—	299	514	1,864
Other sorts,...........	526	—	1,233	—

Statement of the Imports and Exports of the under-mentioned balsams at the ports of the United Kingdom, in the years 1851, 1852, and 1853:—

	1851.		1852.		1853.	
	Import.	Export.	Import.	Export.	Import.	Export
Canada balsam,..	7,923	1,609	21,282	3,461	100	757
Copaiba " ..	69,440	17,024	125,552	26,208	117,040	31,920
Tolu " ..	2,994	208	4,048	623	8,610	1,678
Peru " ..	22,848	27,208	16,893	18,598	34,798	35,695
Other sorts,.....	145	—	319	—	4,443	—

BEER—*bière*, French; *bier*, German—is a malt liquor of any kind, or a spiritous liquor made from any farinaceous grain, but generally from barley, which is first malted and ground, and its fermentable substance extracted by hot water. This extract or infusion is evaporated by boiling in caldrons, and hops, or some other plant of an agreeable bitterness, added. The liquor is then allowed to ferment in vats. It is of different degrees of strength, and is denominated small beer, ale, porter, brown stout, *et cetera*, according to the quantity and nature of its ingredients. Beer is a name given in America to fermenting liquors made of various other materials; and when a decoction of the roots of plants forms part of the composition, it is called *spring beer*, from the season in which it is made. There is also root beer. In Britain, the term *beer* is applied in the same way to fermented liquors made from ginger, spruce, and molasses, as well as to that procured from malt and hops. In the time of TACITUS, whose treatise on the Manners of the Germans was written about the end of the first century of the Christian era, beer was their common drink: PLINY mentions it as being used in Spain, under the name of *cœlia* and *ceria;* and in Gaul, under that of *cerevisia*; he then proceeds to explain, that almost every species of corn has been used for the manufacture of beer. In Europe it is usually made from barley; in India from rice; in the interior of Africa, according to MUNGO PARK, from the seeds of the *holcus spicatus*, spiked or eared wall-hardy. These observations are corroborated by other authors of antiquity; and the *cerevisia* of PLINY evidently takes its name from *Ceres*, the goddess of corn—lexicographers doubting whether it ought not to be written *cererisia*. PLAUTUS more minutely calls it *Cerealis liquor;* that is, liquor used at the solemn feasts in honor of that goddess—the *harvest home;* and both he and COLUMELLA—a famous writer on agriculture, who flourished in the reign of CLAUDIUS, and whose work is therefore coeval with the invasion of Britain by that emperor—called this liquor *zythum*, which, if traced back to its Greek origin, is interpreted, *drink from barley*.

There is no department of the arts and manufactures where Chemistry has exerted a more decided influence than in brewing. In a state of society like the present, when philosophy and enterprise travel with giant strides, and when every branch of technology calls aloud for scientific aid, exact theoretical information cannot be too widely diffused. Notwithstanding the trite saying which has existed from time immemorial, *that any old woman can brew*, it is worthy of remark that few old women, even in literature, are chemists, fewer chemists are brewers, and fewer still are the brewers who, by attention to chemical transformations, have been able to increase the quantity of the useful extract from malt, and to reject the errors, both in theory and in practice, that eventually reduce the labor of the old-woman brewer to futility and loss.

Many operative brewers, in some of the largest town establishments, even now ridicule and despise the idea of chemistry being in any way connected with the art of brewing. Such ignorant prejudices only perpetuate bigotry, and cause an enormous waste of property; the progress of useful art is impeded; and its promoters are ungenerously maligned by a spirit, which knows not the limited range of its own capacity.

In the brewing of beer, the first process of importance which comes under notice is that of malting. Ere this can be proceeded with, however, the grain on which to operate must be chosen, and it is hoped the few following remarks will be found of service, more especially to the inexperienced.

SELECTION OF BARLEY.—Owing to the difference of constituents, energies, and vital functions in grain, according to the diversities of soil, climate, seed, or husbandry, in harvesting, stacking, and thrashing, it becomes necessary that the maltster's skill and experience should be equal to the important task in selecting those samples of corn which, by good management, will produce the richest and most uniform malt; he ought not, moreover, to be restricted by laws which are often arbitrary and unjust, but have free scope in fully exercising his judgment and varying his practice, according to the quality of his grain or other attendant circumstances.

The barley most suitable for conversion into malt grows in large hedgeless tracts of light calcareous soil, and crops, excellent in quality, also thrive on rich loam. Much, however, depends upon the seed: the best possesses a bright, clean, thin, wrinkled husk, tenaciously adhering to a plump, round, well-fed kernel, which, when bruised, appears chalky and sweet, with a germ full, and of a pale yellow color. The barley most profitable for malting is the *rath*, or early ripe, which matures several weeks before other sorts, and is that which agriculturists ought to select, not only on account of its forwardness, but also because it makes superior malt, in consequence of the thinness of its skin and the lusciousness of its nature. Barley is not in a proper condition for malting until it has sweated and seasoned in the stack; if stacked too damp, it will generate so much heat as to destroy the germ. The maltster should be careful in avoiding mixed barley, old and new, as such can never grow evenly or work well together.

The medicinal qualities of barley may not be quite so well known as are its nutritive properties, and therefore a brief glance at these may not prove unacceptable to the reader. In the first degree they are cooling and drying, gently repercussive, abstersive, diuretic, and anodyne, appropriated to the lungs and veins, and galactogenetic. Each variety possesses the same virtues.

Adept brewers, from their long experience, know the best kinds of grain to select.

MALT AND MALTING.—In various parts of Peru, large quantities of maize are converted into *chica;* and it is a remarkable fact, that the grain used in all such cases has been made to undergo the process of malting, a proof that the making of malt must have been known to the inhabitants of that country from a very remote period.

Oats, peas, beans, maize, buckwheat, and common wheat, are all capable of being malted, and have been experimented upon, but barley is most prized for this purpose.

The heaviest grain is recommended, as, if in good condition, it gives malt of corresponding gravity.

What is here intended to be understood by the heaviest malt is, that it shall be of a tender and friable nature throughout, and without hard ends, which are generally more similar in composition and properties to barley than to malt. The perfect article is not always attainable, even with the best skill or management, and it would, on this account, be improper to pass lightly or carelessly over such an important subject.

Malt may be very heavy and yet hard, too much so to bear the name of malt; and the inexperienced may be greatly deceived, unless they have sufficient knowledge to discriminate between the several varieties sent into the market. At the present time the difference is from one to eight shillings per quarter; within the last thirty years, however, it has been as high as from one to sixteen shillings per quarter.

If malt is short of the extract, in comparison with that of the best quality, it is also deficient of fine flavor.

The utmost skill is required to produce a malt of abundant sweetness and friability; when these are attained, it will never be too heavy.

If the brewer is also a maltster, as he ought to be, both in knowledge and in practice, he can procure malt any color he pleases; but even if he be not, there will be no great difficulty in giving the necessary order for any peculiar tint or flavor, either pale, amber, brown, or any intermediate shade.

Much space might be occupied in giving a full dissertation on this subject; it will therefore be treated of in as concise and clear a manner as is possible, so as to include the principles and main features of the most approved systems.

The whole process is comprised under these successive operations: *steeping*, *couching*, *flooring*, and *kiln-drying*.

Steeping.—Without the first—steeping—the grain will not vegetate, which is requisite before its nature can be changed.

The steeping is usually performed in large wooden or stone cisterns, into which the grain to be malted, already screened down and nicely levelled, is shot; it must be charged with liquor to six or seven inches above the barley, and, although the grain has been well cleaned, there will always be some light grains and other matter floating on the surface of the liquor, which must be skimmed off, otherwise, if retained, they would impair the quality of the article, and also the flavor of the beer made from it. However, the improved cultivation of the soil, and the new varieties of barley, have of late years done away with the necessity of skimming.

In consequence of the absorption of moisture, the grain swells about one-fifth in bulk, and increases about fifty per cent. in weight, one hundred pounds of barley thus becoming one hundred and fifty.

The object of steeping is to expand the farina of the barley with humidity, and thus make the seed fit for germination, when subsequently exposed to the air. Too much steeping is injurious, because it prevents the germination at the proper time, in consequence of the air being excluded whilst the superabundance of water is spontaneously evaporating; it is hurtful, also, in extracting a portion of the saccharine matter. The maceration is known to be complete when the grain may be easily perforated with a common needle, and is swollen to its full size; or if a barley-corn, when taken between the thumb and fingers and pressed, sheds its flour upon them, it is ready; but if it continues entire, or its substance exudes as a milky juice, it is either, in the first instance, not sufficiently steeped, or, in the latter, the steep has been too long continued, and the grain is spoiled for germination.

In warm weather it sometimes happens, that, before the grain has completely swelled, the water becomes acescent; this circumstance, which is very soon discovered, may be immediately remedied by drawing off the foul liquor by means of the tap at the bottom of the cistern, and replacing it with fresh cold water. No harm is done even if it be renewed three times during one steep.

The time of steeping, which varies according to the temperature and other circumstances, requiring in winter a longer and in summer a shorter period, is reckoned technically by the term *tide*, each being of twelve hours' duration. In winter it may extend over five and a half or six tides, from the time the liquor is put into the cistern to the time of letting, sixty-six or seventy-two hours; at others it will cease to swell much sooner, but, as a general rule, it should lie in the cistern until it will no longer swell, after which, the liquor being drawn off, it should be left to drain for six hours before it is emptied into the couch. If now the skin, which is somewhat loosened, be partially removed from the kernel, and the two ends are slightly pressed, the latter will be seen to be partly separated.

The Couch.—The water being drawn off, and a fresh quantity occasionally passed through, to depurate the grain from any slimy matter which may have been generated, it is laid upon the stone flag-floor of the couch in square heaps, from twelve to sixteen inches in depth, and left in that position for twenty-four hours.

The bulk of the grain being greatest at this time, the revenue officers may, if they think fit, gage it. The surface of the barley is now so entirely freed from moisture, that it does not feel damp. By degrees, however, it becomes warm, its temperature being 10° above that of the atmosphere, and it gives out an agreeable fruity smell. If at this time the hand is thrust into the heap, it gets bedewed with moisture, and at this sweating stage the germination commences; the fibrils of the radicle first shoot forth from the tip of every grain, and a white elevation appears, which soon separates into three or more rapidly increasing radicles. About a day after this appearance, the plumula—acrospire of the maltster—peeps forth from the same point, and would proceed under the husk until it appeared at the other end of the seed, as a green leaflet; but this never happens in malting, as the operation is finished before it takes place.

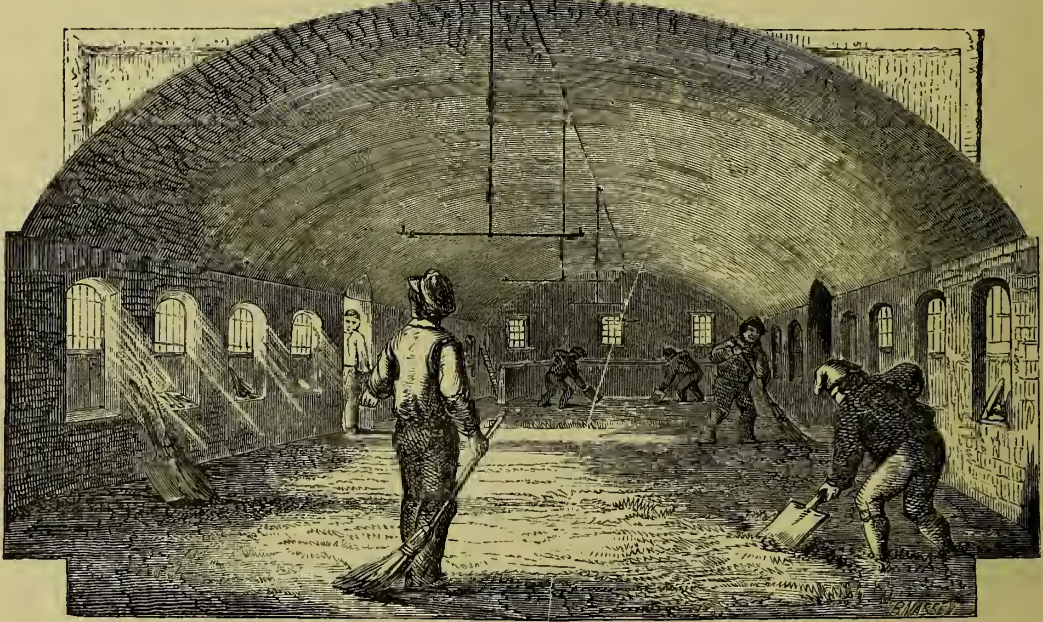
About ninety-six hours after the barley has been taken out of the steep, the heat is the greatest, consequently the radicles increase in length with great rapidity, and must be checked by artificial means, which constitute the chief art of the maltster.

The barley must be spread out thinner upon the floor, and turned several times a-day—as shown in Fig. 150—the interior being always brought, by the spades of the workmen, to the surface. The depth, originally fifteen or sixteen inches, is lessened slightly at each turning, till it is at last not more than three or four inches. Two spadings per day are generally requisite. At this period of spreading or flooring, the temperature in England is about 62° Fahr., but in Scotland only 56° or 57°.

The rudiments of the stem, or the plumula, sprout forth about a day after the appearance of the radicles.

To a limited extent the barley absorbs oxygen and emits carbonic acid, just as animals do in breathing; the grain loses from one and a half to three per cent. of its weight upon the malt floor, a portion of this being due to waste particles. As the acrospire creeps along the surface of the seed, the constituents undergo a remarkable alteration. The gluten and mucilage in a great degree disappear, the color becomes whiter, and the substance so friable that it crumbles into meal between the fingers. This is the great object of malting, which is accomplished when the acrospire has reached the end of the seed. At this period the growth must be completely stopped. The duration of the germination in England may be reckoned fourteen days; but in Scotland eighteen or even twenty-one are required, owing to the lower temperature of the couch.

Fig. 150.



The shorter the period within these limits the better, as there will be a quicker return of capital, and the malt produced is superior. In dry weather it is sometimes necessary to moisten the barley upon the couch.

If an offensive odor, somewhat resembling that of rotten apples, be observed to arise from the couch, it is a bad omen, showing that either the quality of the barley was inferior, or that, through carelessness, the workmen have crushed a number of the grains in turning.

On this account, when the weather causes germination too quickly, it is better to arrest it by spreading the heap out thinner than by turning it too often.

Comparing different samples of barley, it will be found that the best develop the acrospire quicker than the radicles, and thus give rise to a greater production of the saccharine principle; this conversion advances and keeps pace with the acrospire, so that the portion of the grain to which it has not reached remains in its unaltered starchy state. It is never complete till the acrospire has attained the opposite end to that from which it sprung; hence one portion of the corn may be *sugary*, while the other is still tasteless. If the grain was allowed to vegetate beyond this term, the radicles being one-third of an inch long, the future stem would become visibly green, it would shoot forth rapidly, the interior of the grain would appear milky, a complete exhaustion of all its useful constituents would ensue, and nothing but husk remain.

In France, the brewers, who are generally their own maltsters, seldom leave the barley on the couch longer than eight or ten days, which is too short a period, even when allowance is made for the extra warmth of the climate; hence the wort, made from the same quantity of malt, is much inferior to that of the English brewer.

At the conclusion of the germination, the radicles have become once and a half as long as the barley, and are so contorted that the corns hook one into another, but the acrospire is just beginning to make its appearance.

A moderate temperature is best fitted for malting; it cannot, therefore, be *well* carried on in the heat of summer or the cold of winter. Malt floors should be placed in substantial thick-walled buildings, the more concealed from the rays of the sun the better, so that a temperature of 59° or 60° Fahr. may uniformly pervade the interior. They are said by some to be better when sunk slightly under the surface of the ground, provided that the situation is dry.

During germination, portions of the glutinous constituent of the grain disappear, which it is conjectured have passed into the radicles, while a portion of the starch is converted into sugar and mucilage. The change is similar to that which starch undergoes when dissolved in water, and digested at a heat of about 160° Fahr. with a little gluten. The thick paste becomes by degrees liquid, transparent, and sweetish to the taste, the solution containing sugar and gum mixed with some unaltered starch. At the same time the gluten undergoes a change and becomes acescent, so that only a certain amount of starch can be thus modified by a quantity of gluten. By the artificial growth upon the malt floor, the whole of the gluten and albumen is not decomposed, and only about one-half of the starch is changed into sugar; by a continuance of the germination, the remainder would only assist the growth of the roots and stems, but it is nearly altogether converted into sugar, without any very great waste of substance, in the brewer's operation of mashing.

If the grain is suffered to sprout in the couch, it will never be even afterwards, as those corns which are sprouted will attract more than their proper share of moisture; moving and turning in due time will, however, retard this, and cause each corn to shoot almost simultaneously.

The Flooring.—In this operation the grain is turned inside out from the couch into the bed, which is made to occupy two or three times as much space as the former, according to the temperature. It may lie here for about six hours, observing in the interim whether the grains are commencing to shoot; or, if this is not the case, giving it a gentle turning, and spreading it out thinner, before the expiration of the period named; it may be laid all the width of the floor, and permitted to remain for another six hours, when all the healthy corns will be sprouted; it is then again thinned, and after this, while it is in full vigor, often turned; by this means the root is kept short and bushy, and retains the moisture as long as is requisite, to the period of its withering, if the process be of sufficient duration, *without sprinkling*.

The root begins to fade about the eleventh or twelfth day.

If, on taking a handful of the grain from the floor, it smells faint, and the skin is glossy or wet, it requires turning. After this it will smell fresh, and the grain, instead of being glossy, will be dry. If the turning is omitted at the proper time, the root will be of unequal length.

On the grain beginning to wither, it may be spread out thicker, to generate a little more warmth, and to mellow it, still keeping it frequently turned, to prevent a glossy appearance, until the moisture is further expelled, and also to retard the progress of the acrospire.

The grain, when ready for drying, must easily rub to meal between the fingers, after being deprived of the skin.

Kiln-drying.—When the malt has become perceptibly dry to the hand upon the floor, it is taken to the kiln and hardened with artificial heat, to prevent all further growth, and enable it to be kept, without fear of change, for use.

The malt should be evenly spread upon the drying cloth, or floor, in a layer varying from three to ten inches in thickness, according to the variety which is to be produced, and a heat of from 90° to 100° Fahr. steadily maintained, till the moisture is for the most part driven off. During this time the malt must be turned over, at first frequently, and, towards the conclusion, every third or fourth hour. When nearly dry, the temperature of the kiln should stand between 145° and 165° Fahr., and this heat must be maintained till the grain has acquired the desired color.

The fire is now allowed to die out, and the malt is left on the kiln till sufficiently cool, this result being greatly accelerated by the stream of cold air rising up through the bars of the grate. Thoroughly dry brown malt may, however, by damping the fire, be taken hot off the plates, and cooled in some contiguous apartment. The kiln-drying should not be hurried; many persons occupy two days in the operation. The malt, when prepared, must be kept in a dry loft, where it can be occasionally turned over till used.

The temperature of the kiln should, in all cases, be most steadily maintained, and, when required, gradually elevated.

If the drying commences with too great a heat, the outer part of the grain hardens, and prevents the interior moisture from evaporating; should this be driven off by too high a temperature, the husk will, in all probability, split, and the farina become horny and very refractory in the mash.

It is preferable, therefore, to brown malt by a long-continued moderate heat, than to apply a strong one for a shorter period, which might carbonize a portion of the mucilaginous sugar, thereby deteriorating the value of the product.

In this manner the sweet, very often changes to a bitter principle.

During the drying, the roots and acrospire of the barley become brittle, and are, by the friction of turning, *et cetera*, broken off, and are afterwards separated by a fine wire sieve—Fig. 151, in the next page. This operation is termed cleaning.

The *bulk* of good malt exceeds that of the barley from which it was fabricated, by about eight or nine per cent.

The benefit derived from kiln-drying is not merely confined to the expulsion of the moisture, a portion of the starch which was unchanged is by it converted into sugar in a double or twofold way: firstly, by the action of the gluten upon the fecula at an elevated temperature; and, secondly, by the incipient roasting the starch is subjected to, giving it a kind of gummy nature.

This is illustrated by the fact that malt, freed from moisture as much as possible in a dry atmosphere without heat, yields much less saccharine extract than that dried ordinarily. Moreover, kiln-dried malt has a peculiar, agreeable, and faintly-burnt taste, probably from some empyreumatic oil generated in the husk, and which imparts its flavor to the beer, at the same time that it assists in preserving it. The skilful preparation of the malt must necessarily exercise a very great influence on the worts which are prepared from it. If the germination be pushed too far, a portion of the valuable matter is wasted, while, if it is not carried on sufficiently long, the malt will be too raw, and much of its starch will remain insoluble; if it is too highly kiln-dried, a portion of its sugar will become caramelized and bitter; and if the sweating was irregular or imperfect, much of the barley may be lumpy or useless.

Fig. 151.

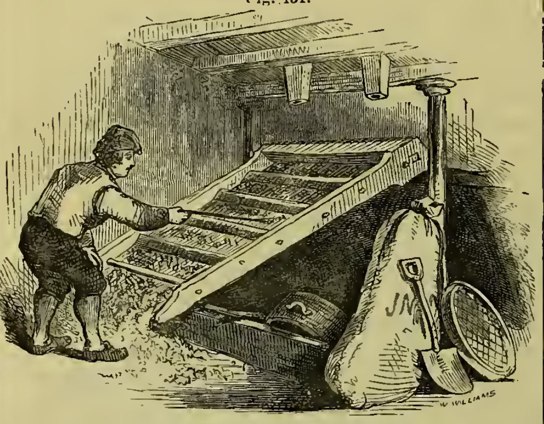


Fig. 152.

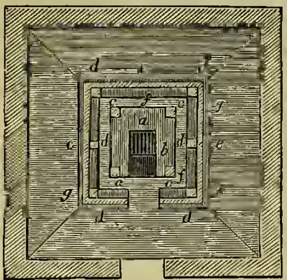


Fig. 153

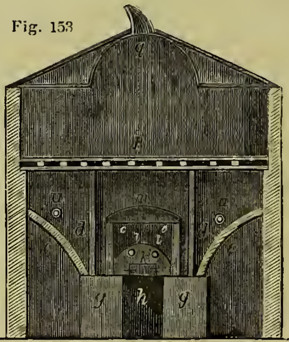


Fig. 154.

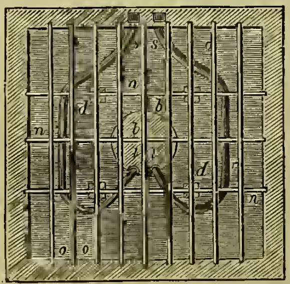
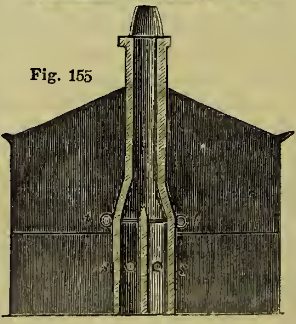


Fig. 155



The grains of good malt are round and full, break freely between the teeth, have a sweetish taste, an agreeable smell, and are full of soft flour. They give no unpleasant taste on being masticated; are not hard, so that they will give a free white streak, like chalk, when drawn contrariwise to the fibres of wood; and, lastly, will swim on water, as is not the case with unmalted barley.

Malt-kiln.—The construction of a well-contrived malt-kiln is shown in Figs. 152, 153, 154, 155: the first being the ground plan; the second, a vertical section; the third, a horizontal, and the fourth, a vertical section in the line of the malt plates. The same letters in each of the figures are indicative of similar parts.

In the middle, upon a wall of brickwork four feet high, is supported a cast-iron cupola-shaped oven, and beneath it are the grate and ash-pit. The smoke escapes through two equidistant pipes into the chimney. *a* is the grate, nine inches below the sole of the oven, *b; c c c c*, are four strong nine-inch pillars of brickwork bearing the stone lintel, *m; d d d d d d*, are similar supports for the girder and joists, upon which are laid perforated plates; *e* indicates a vaulted arch on each of the four sides of the kiln; *f* is a space between the kiln and the side arch, allowing of the inspection and cleaning of the kiln; *g g*, walls, on which the arches rest, on each side of the kiln; *h*, the ash-pit; *k* is the furnace-door; and *l l* are junction pieces connecting the pipes, *r r*, with the kiln.

These smoke-draughts rest about three feet from the walls, and a similar distance from the malt-plates, upon iron supports secured to the arches. They are indicated in the vertical section—Fig. 153—by the letters *u u;* at *s s*—Fig. 155—they enter the chimney, to which is supplied two register or damper plates, intended to regulate the draught. These registers are represented by *t t*; the lintel, *m*—Fig. 153—is intended to cause the heat to spread laterally, instead of ascending in one mass in the middle, and prevents any combustible particles from falling upon the iron cupola; *n n* are main girders of iron supporting the joists, *o o*, of the same material, upon which the perforated plates, *p*, lie; *q* is a vapor pipe in the middle of the roof, allowing the steam of the drying malt to escape.

This kiln may be heated either with coal or wood. The size is about twenty feet square, but it may either be proportionally enlarged or diminished, as seems advisable. The perforated floor should be large enough for the contents of one couch or steep to be spread out upon.

It can be heated by means of steam pipes, laid irregularly, or in parallel lines under it, or a wire-gauze web might be extended upon such pipes. This steam apparatus might, without danger, be supported by joists of timber. For drying the pale malt of the brewers, this plan is well adapted.

Gas-Drying.—A patent was recently granted to Mr. Hallewell of Leeds, for improvements in malting, in consequence of drying by gas instead of the usual process. This invention is stated to augment the yield of malt twelve per cent., that is, something like one bushel out of every eight malted.

The malt to be dried is laid on an ordinary perforated floor of iron plates, and very small jets of gas are applied within 5½ inches of its under side.

During the first twelve hours the temperature rises to 70° Fahr.; at the expiration of forty hours, it reaches 120° without any increase in the consumption of gas.

When this degree has been attained, the malt is, comparatively, perfectly dry, and quite pale. It is very fine in appearance, and remarkable for its peculiar sweetness; and being freer from moisture than most malt kilned in the usual way, as on analysis it only gave 5·89 per cent.—see page 243—it passes through the rollers in grinding in one-fourth less time than the ordinary product. The cost of exsiccation is said to be about two per cent. over that by the common method; but as the produce is above twelve per cent. more, there is a clear advantage.

According to Mr. HALLEWELL, the worts are drawn so closely from his malt as to be below four pounds per barrel gravity. He says:—If the worts were drawn as low from cinder-dried malt, the acid of the liquor would be so strong as to be quite nauseous and injurious.

The advantages and beneficial effects of this new system of desiccation, no doubt, arise in part from the small quantity of water which the malt contains, and the absence of sulphur, of which there is always a certain amount in the coke ordinarily used for drying; the result is the evolution of sulphurous acid, which certainly affects the malt, bleaching it, and leaving some sulphuric acid behind, which, when water free from carbonate is employed, seriously interferes with the fermentation.

Regarding the truth of the foregoing statement of the increase consequent upon the use of the gas-dried malt, the Editor has had no immediate opportunity of judging; but it has been corroborated by very eminent brewers in London and elsewhere. This invention must be of material importance in other cases than that of making beer; but especially brewers will benefit by it, and more so when the duty on malt is high.

MALTING IN MUNICH.—The barley is steeped till the acrospire seems to be quickened; a circumstance indicated by a swelling at the end of the grain which was attached to the footstalk, as also when, on pressing a pile between two fingers against the thumb nail, a slight projection of the embryo is perceptible. As long, however, as the seed-germ sticks too firm to the husk, it has not been steeped enough for exposure on the underground malt floor. Nor can deficient steeping be safely made up for afterwards, by sprinkling the malt-couch with a watering-can, which is apt to render the malting irregular. The steep-water should be changed repeatedly, according to the degree of foulness and hardness of the barley: first, six hours after immersion, having previously stirred the whole mass several times; afterwards, in winter, every twenty-four, but in summer, every twelve hours. It loses none of its substance in this way, whatever vulgar prejudice may think to the contrary. After letting off the last water from the stone cistern, the Bavarians leave the barley to drain in it during four or six hours. It is now taken out, and laid on the couch floor in a square heap, eight or ten inches high, and it is dexterously turned over, morning and evening, so as to throw the middle portion upon the top and bottom of the new-made couch. When the acrospire has become as long as the grain itself, the malt is carried to the *withering* or drying floor, in the open air, where it is exposed in dry weather, during eight to fourteen days, being daily turned over three times with a winnowing shovel. It is next dried on a well-constructed cylinder, or flue-heated malt kiln, at a gentle, clear heat, without being browned in the slightest degree, while it turns friable into a fine white meal. Smoked malt is entirely rejected by the best Bavarian brewers. Their malt is dried on a series of wove-wire horizontal shelves, placed over each other; up through the interstices or perforations of which, streams of air, heated to only 122° Fahr., rise from the surfaces of rows of hot sheet-iron pipe flues, arranged a little way below the shelves. Into these pipes the smoke and burned air of a little furnace on the ground are admitted. The whole is enclosed in a vaulted chamber, from the top of which a large wooden pipe issues, for conveying away the steam from the drying malt. Each charge may be completely exsiccated on this kiln in the space of from eighteen to twenty-four hours, by a gentle uniform heat, which does not injure the diastase, or discolor the farina.—*Ure.*

In concluding the account of Malting, the Editor cannot refrain from making a comparison between the present system and the ingenious and excellent one lately patented by Mr. W. L. TIZARD, the eminent mechanical and consulting engineer of London.

It is well known that even an ordinary malting establishment includes an extensive range of buildings, containing a cistern, a couch, extensive floors, and the kiln. Mr. TIZARD's newly-invented malting apparatus consists of a vertical cylinder, containing a series of wire trays, provided with sprinkling and turning apparatus and steam pipes, vacuum and plunge pumps, vacuum and pressure gages, thermometer, *et cetera*, and worked throughout the whole year with 75 per cent. less labor, and 50 per cent. less fuel than the old one. Experienced men admit, that of late the harvests have been so unpropitious, that the farmer is unable to secure his barley crop sufficiently dry for the purpose of the maltster, and the latter asserts that it is necessary to dry or sweat the grain artificially on a kiln, previous to its saturation with water in the cistern. The process of sweating is, however, neglected, on account of the great trouble it gives, or from there not being an extra kiln provided for the purpose. Hence the malting is commenced in a slovenly and imperfect manner. The temperature of the steeping liquor, and the number of hours allowed for the saturation of the grain, are also disregarded as matters of routine, notwithstanding that they are points of very great importance as affecting its manufaoture into malt. With the new apparatus, the process is commenced and finished in one vessel, which is a cylinder, occupying but one-twentieth the area of a malt-house. The barley gravitates from the stores above into each tray; after which the door is screwed up, and the cylinder made air-tight. The conversion of the grain into malt commences thus:—A current of steam is passed through a series of tubes lying under the bottom of each tray, which imparts its caloric to the grain, by which all superfluous moisture and atmospheric air escape from each corn in the form of vapor. When the contents of the cylinder are heated to the temperature of about 100° Fahr., the vacuum pumps are put in motion, by which such vapor is extracted, and a partial vacuum created. The atmospheric pressure being thus removed, and the dilatation of the grain effected, a vacuity necessarily exists in the pores and interstices of each corn. In this favorable condition it imbibes steeping liquor at a temperature of 53°. Thus the steeping is accelerated, and a perfect saturation produced. The grain is now allowed to germinate; but throughout this interesting process, the laws of nature are subject to the controlling hand of science, which has here brought to its aid all the mechanical means necessary to achieve the great object of the maltster, namely, that of thoroughly exposing and making available the whole farina of the corn, without which the article would be imperfect. This is effected and kept within the range of proper temperatures by a steady sprinkling and evaporation of cold water, accompanied by the constantly evolving carbonic acid, which are together removed by the vacuum pumps. On the other hand, its temperature might be increased, and the process accelerated, by occasionally applying the plunge pumps, which subjects the manufacture to atmospheric pressure. The great revenue arising from the malt duty will, to a moral certainty, render this invention as acceptable to her Majesty's Commissioners of Excise, and the Chancellor of the Exchequer, as to the honest maltster; inasmuch as it admits of being locked up, like a rectifier's still, as soon as the barley is introduced, and need not be opened till the manufacture is complete, and the malt ready to be removed to the stores; so that the whole process is proof against fraud, and the daily supervision of the officers of Excise could be dispensed with.

Space will not admit of a disquisition on the comparative merits of the old and new processes of couching, flooring, sprinkling, germinating, turning, heaping, and withering, but a brief description of the curing or finishing process, termed *drying*, cannot be dispensed with. This can be accomplished without the painful experience of having destroyed the vitality of the grain by the barbarous shovel, or the soles of the feet; by excessive light; cold or hot currents, or other incidental causes. Presuming, then, that the new apparatus has supplied the necessary moisture and atmospheric air, and abstracted all superfluous caloric, and the carbonic acid gas generated by the germination of the grain, which it cannot fail to do to perfection, the drying is performed as follows:—Steam is passed through the pipes, speedily raising the temperature of the contents of the cylinder to 90° or 100°. The vacuum pumps are also put in requisition, which immediately extract the steam as it flows out of the grain, preserving a partial vacuum on its exterior, during the withdrawal of the whole of the moisture. The malt is thus thoroughly dried in a distended form, and its original plumpness is preserved. It is acknowledged that the palest malt produces the largest amount of extract, and that it cannot be too pale if properly desiccated. The apparatus thus briefly alluded to, has been designed by a practical maltster and brewer, with the view of advancing one of the most important of our national manufactures, and one which is most susceptible of improvement, the common malting processes being rude and unsatisfactory in the extreme. Here is a complete set of apparatus to enable an intelligent operator to control the various processes of sweating, steeping, and converting the farina of his corn into sugar, and of exsiccating it to perfection, without imparting the least possible color or contraction of the grain. Indeed, malting is now reduced to a science, and cannot fail to meet with the support of the Government, and the most intelligent of the malting and brewing communities. For the pale ale brewer, this invention ought certainly to be invaluable, and the Editor would strongly recommend the leading firms at Burton and elsewhere to introduce the apparatus into their establishments.

Before proceeding further, it will be advisable to dwell very concisely on the composition of raw and malted barley.

The analysis of barley-meal has been made by EINHOFF; but the results which he obtained are so extremely discordant with those obtained by others, that they do not at present seem to be worthy of confidence.

PROUST affirms that barley contains a peculiar proximate principle, which, from the Latin name of the grain, has been denominated *hordein.* He describes it as a yellow, granular, woody powder, in appearance very much resembling sawdust; and says that it disappears in great quantity during malting, being resolved chiefly into starch and sugar. Does it not disappear wholly?

Annexed is the mean of ten analyses of barley performed by HERMBSTADT:—

	Centesimally represented.
Water,	10·48
Husk,	11·56
Gluten,	4·92
Albumen,	0·35
Starch,	60·50
Sugar,	4·66
Gum,	4·51
Oil,	0·35
Soluble phosphates, *et cetera*,	0·36
Loss,	2·31
	100·00

PROUST states that barley-meal contains—

Hordein,	55·0
Starch,	32·0
Sugar,	5·0
	92·0

Dr. T. THOMSON gives no hordein, but—

Starch,	88·0
Sugar,	4·0
	92·0

The analyses of PROUST and THOMSON agree exactly, only one takes the 88·0 to be solely starch; while the other assumes it to be a peculiar principle and that body.

The same statement is applicable to the principal constituents of malt, as given by these chemists, thus:—

	Proust.	Thomson.
Starch,	56·0	69·0
Hordein,	12·0	—
	68·0	69·0

The sugar found in the barley was, no doubt, the result of the action of some of the reagents employed by the above chemists on the starch.

Einhoff's analysis gives sugar in the same proportion as Proust and Thomson, but represents the quantity of starch as more than double that found by the former.

Dr. Thomson is of opinion that the hordein, instead of being a proximate principle, is merely starch in a peculiar state, somewhat similar to the fibrous matter of potatoes, malting having the effect of converting it into starch and sugar by destroying a certain unknown glutinous substance, which holds the particles firmly together.

The presence of a singular substance in barley-meal in so great a quantity as more than fifty per cent., its being woody and insoluble in water, both cold and boiling, its disappearing during the malting, and the increase of gum, sugar, and starch in consequence, are properties not attributable to any component part of the grains with which chemists have hitherto been acquainted. Hence, hordein has been, and is now, admitted by many to be a peculiar substance. According to Gregory, its composition is $C_{12} H_8 O_8$, or $C_{12} H_{10} O_{10}$.

If this analysis be correct, it is almost impossible to view hordein as a principle; it seems rather to be an allotropic modification of starch. It is very probable that this state is owing to some impurity or extraneous matter, and that, could this be removed, it would be found to consist of starch only. There is no doubt that, at some future period, the number of the principles now regarded as peculiar will be reduced, and many of them proved to be identical with each other, *only* existing under different circumstances.

The amount of inorganic matter in different specimens of barley, varies very considerably. This might be anticipated from the fact, now generally admitted, that the nitrogenized or nutritive principles of grain or seeds, bear a relation to the phosphoric acid present; thus, if the quantity of the latter be small, it follows that the amount of nitrogen is proportionally deficient, and the nutritive effect of the grain will be comparatively low in the scale, because the solubility of the albuminous matters, and, therefore, their capability of being carried into plants, appears to depend on the presence of the phosphates.

Dr. R. D. Thomson says—In the analyses which have been published of this nature, the manipulators have omitted to state whether the husks were included in the grain burned by them. In the following results the omission has been filled up:—

	Barley Flour.	Barley with Husks.		
	R. D. Thomson.	R. D. Thomson.	Horsford.	Way.
Inorganic matter per cent.,	4·02	3·20	2·70	2·34

Horsford's is the mean of ten, and Way's of four experiments.

The following was found to be the composition of the ash of barley and malt:—

	Centesimally represented. R. D. Thomson. Barley.	Malt.
Potassa,	16·00	14·54
Soda,	8·86	6·08
Lime,	3·23	3·89
Magnesia,	4·30	9·82
Oxide of iron,	0·83	1·59
Phosphoric acid	36·80	35·34
Sulphuric acid	0·16	—
Chlorine,	0·15	trace.
Silica,	29·67	28·74
	100·00	100·00

The composition of a sample of barley, and of malt made from it, thus showing the alteration in the grain by malting, is here given:—

	Barley.		Malt.	
	Natural state.	At 212°.	Natural state.	At 212°.
Carbon,	41·64	46·11	42·44	43·93
Hydrogen,	6·02	6·65	6·64	7·00
Nitrogen,	1·81	2·01	1·11	1·29
Oxygen,	37·66	41·06	43·08	46·51
Ash,	3·41	4·17	1·68	1·27
Water,	9·46	—	5·05	—
	100·00	100·00	100·00	100·00

The mean of a number of experiments relative to the loss which barley sustains by malting, indicated nineteen per cent.

The whole of the loss is not solid matter, as barley uncrushed contains 13·1 per cent. of water; and malt, in the same condition, 7·06 per cent. Mr. E. E. Holden, student in the Editor's college, found in ordinary cinder-dried malt, 7·68 per cent.

There thus remain thirteen per cent. of solid loss.

A mean of several trials gave for the ash of barley 3·0; and for that of malt, 2·52 per cent. Now, as one hundred of the former are equal to eighty of the latter, the quantity of ash which malt should contain is 2·42, if the loss of organic and inorganic matter was equable, which it is observed to be, almost approximately, from this experiment; for the relation of the ash which has disappeared, or 0·48 per cent., bears almost the same proportion to the organic matter removed, as the total quantity of ash in barley does to the whole of the organic matter in that grain. Thus, barley contains eighty-four per cent. of *dry* organic matter and three per cent. of ash, while malt has lost 0·48 per cent. of ash, and 12·52 of organic matter, and by calculation—

As 3 : 0·48 :: 84 : 13·4.

A remarkable coincidence, as if proving that water is incapable of removing the inorganic portion of plants, until the organic matter has undergone such a change as to allow the ash to separate.

From the above, the loss sustained by barley in malting may be stated thus:—

Water,	6·00
Saline matter,	0·48
Organic matter,	12·52
	19·00

At the request of the Editor, who was desirous of ascertaining the amount of soluble matter extracted from malt by mashing, Mr. E. E. HOLDEN performed an experiment on the small scale, but as proportional with ordinary operations as possible, and found that, on repeatedly treating it with water, at an average temperature of 150° Fahr., 14·5 per cent. of residue, technically termed *brewer's draff*, was obtained, showing a loss of 85·5 per cent., water included, or 300 pounds per quarter of malt.

The composition of fresh draff—brewer's grains—is thus given by FROMBERG :—

	Centesimally represented.
Water,	75·85
Gum,	1·06
Other organic matter, chiefly husk,	21·28
Organic matter, containing nitrogen-protein-compounds,	0·62
Inorganic matter,	1·19
	100·00

From Mr. HOLDEN'S experiment and FROMBERG'S analysis of the draff, it would appear that, when the mash is properly managed, the whole of the available or useful matters in the malt are dissolved out by the brewer.

The ash left, on burning the draff, consists of—

	Centesimally represented.
Chlorides and sulphates,	7·60
Phosphates of potassa and soda	2·11
Phosphates of lime and magnesia,	48·00
Silica,	41·51
Loss,	0·78
	100·00

WATER.—Good water in a brewery is a great desideratum, and the reader's attention is now directed to this subject.

Perhaps nothing in nature is more variable in character than this apparently simple fluid, which is not the *aqua pura* which it seems, and which many believe it to be, but a heterogeneous mixture of alkaline and metallic salts, acids, gases, and occasionally even animal and vegetal matter, some being held in chemical union, and others in mechanical suspension. Pure water, or *oxide of hydrogen*, is attainable only by art.

Some brewers prefer soft and others hard water, whilst a few are quite indifferent on this point.

Were the density of the worts, and the value of cold water, for refrigeration and other purposes, properly considered, there would be little hesitation in their choice; and it is of importance to arrive at a correct conclusion on this point; for, though a brewer already established can seldom choose a different spring or stream, the case is much altered when the site of a new brewhouse is to be selected.

Water free from saline matter, or that holds it in very small quantity, is unfit for the brewery. The softest is in the state of snow, which, according to BERGMAN, is destitute of all gaseous bodies, so that fish cannot live in it.

The Editor does not deem it necessary to give a long dissertation upon this liquid, as nearly every one at all acquainted with brewing knows, that water which contains a large quantity of gypsum—sulphate of lime—earthy carbonates, and *no organic matter*, is best adapted for his purpose.

Many, no doubt, wonder why hard water answers so much better in the preparation of malt than soft. A few reasons, to account for this, may not be unacceptable to the reader.

Dr. HASSALL says:—During ebullition, the excess of carbonic acid in the water, by which the carbonates of lime and magnesia are retained in solution, is expelled, and those salts are precipitated. Again, the alkaline phosphates present in malt have the power of converting sulphate of lime into phosphate, which is thrown down; an alkaline sulphate, which is soluble, being synchronously formed. The greater part of the phosphate of lime produced is redissolved in the acid generated during the fermentation; consequently the water, from being hard, thus becomes comparatively soft, and in this state is well suited for extracting the active properties of the malt and hops.—*Hassall.*

This is entirely speculative, and is not based on experiment; nevertheless, the theory is ingenious.

Another advantage in the use of hard water presents itself, which is, that more saccharine matter can be left in the beer, by which the fulness and flavor will be increased, and the liability to become acid prevented.

Water loaded with organic matter, like that of the Thames, is a decided loss to the brewer, as the vegetal and animal remains are decomposed during brewing, and carry with them some portion of the strength of the wort, besides rendering it and the beer liable to spoil.

Messrs. ALLSOPP and SONS, Messrs. BASS and Co., Messrs. SALT and Co., and other eminent Burton brewers, have long been celebrated for the quality of their beer, and many conjectures have been made to account for the excellence and superiority of the article brewed in that locality. The success depends in a very great measure upon the quality of the water used; the consequences of which, in brewing, have been scientifically elaborated. It is a very hard water, remarkable for its quantity of earthy sulphates and carbonates; and, *à priori*, it would be considered but ill adapted for the purposes of the brewer. This is not the case, however, as long experience has shown.

The following analysis by Dr. BÖTTINGER, brewer to Messrs. ALLSOPP and SONS, expresses the composition of the water used in that celebrated establishment, and conveys at once an idea of the general properties of this important menstruum :—

	Amount of ingredients in the imper. gallon. Represented in grains.
Chloride of sodium,	10·12
Sulphate of potassa,	7·65
Sulphate of lime,	18·96
Sulphate of magnesia,	9·95
Carbonate of lime,	15·51
Carbonate of magnesia,	1·70
Carbonate of iron,	0·60
Silicic acid,	0·79
	65·28

Some years ago, Mr. COOPER of London analyzed some water taken from a well at the brewery of Messrs. BASS and Co., in which he found—

Carbonate of lime,	9·93
Sulphate of lime,	54·40
Chloride of calcium,	13·28
Sulphate of magnesia,	0·83
	78·44

All the water used at Burton for brewing is spring water, and not that of the river Trent, as has been erroneously supposed.

On boiling, it deposits a large amount of carbonates of lime and magnesia, besides a small quantity of sulphate of lime; a little iron, which it contains, becomes also eliminated.

The geological formation from which this water appears to emanate, is New Red Sandstone; in the immediate vicinity of Burton there are large strata of new red marl, with a considerable amount of gypsum.

The water employed at the brewery of Messrs. TETLEY and SON, Leeds, bears some analogy to the preceding, as will be seen on referring to the annexed analysis by the Editor:—

	Per gallon.	
Carbonate of lime, Carbonate of magnesia,	19·78	grains.
Carbonate of the protoxide of iron,	0·93	"
Sulphate of lime,	4·97	"
Sulphate of soda,	13·09	"
Sulphate of magnesia,	9·73	"
Chloride of sodium,	7·11	"
Chloride of magnesium,	4·74	"
Loss,	1·72	"
	62·07	

The three waters contain a varying amount of carbonic acid in the uncombined state, keeping the carbonates in solution.

From the above the Editor would suggest, that when brewers in certain districts are compelled to use soft water, or that which runs off moors or fens, for want of better, they should impregnate them at second hand with gypsum, or with such limestones as are easily procurable. This plan has been found most serviceable, and the ale obtained from such artificial water has nearly equalled the renowned product of Burton.

HOPS.—The wort, as prepared from malt, is unpalatable and viscous; and to bring it into a potable state, and insure the permanence of its virtues, it has been found necessary to make some addition to it previous to fermentation. This effect is best produced by means of *hops*, the properties of which, and the characteristics by which they may be selected, will now be concisely pointed out.

Hops are the strobiles or catkins of *humulus lupulus*, a diœcious plant belonging to the natural order Urticaceæ, the culture of which was first introduced into England from Flanders in the reign of HENRY VIII.

The various parts of the hop are, scales, nuts, and lupulinic grains or glands. The scales are the enlarged and persistent bracts enclosing the nuts, which are small, hard, nearly globular, and covered with aromatic superficial glands, commonly termed *yellow powder* or *lupulin.* These form the most important part of the strobiles.

Dry hops ought to yield about one-sixth of these grains. They are usually mingled with sand.

PEREIRA says they are rounded, of a cellular texture, golden-yellow colored, somewhat transparent, and are sessile, or nearly so.

The common centre around which the cells are arranged has been denominated the *hilum.* They lose their spherical form by exsiccation, and, when placed in water, give out an immense number of minute globules. Under different circumstances they become ruptured, allowing an inner envelope to escape. TURPIN states that they consist of two vesicles, one eviscerating the other, the interior containing *globules*, *aromatic oil*, and *a gas*, and affirms that, in the bubbles of disengaged gas, a large number of crystals are formed.

The scales and lupulinic grains have been analyzed by PAYEN, CHEVALLIER, and PELLETAN, with the following results:—

LUPULINIC GRAINS.

	Centesimally represented.
Volatile oil,	2·00
Bitter principle—lupulin,	10·30
Resin,	55·00
Lignin,	32·00
Fatty, astringent, and gummy matters, osmazom, malic and carbonic acids, salts, as malate of lime, acetate of ammonia, chloride of potassium, sulphate of potassa, *et cetera*,	traces.
Loss,	·70
	100·00

The scales were found to consist of astringent matter, inert coloring matter, chlorophyl, gum, lignin, and salts of potassa, lime, and ammonia, containing acetic, hydrochloric, sulphuric, nitric, and other acids.

The scales usually have lupulinic matter adhering, from which it is almost impossible to free them.

Dr. IVES also examined the lupulinic grains, and obtained—

	Centesimally represented.
Tannin,	4·16
Extractive,	8·33
Bitter principle,	9·16
Wax,	10·00
Resin,	30·00
Lignin,	38·33
Loss,	·02
	100·00

The volatile oil exists in the lupulinic grains, and is procured by distilling them or the hops with water. It has a yellowish color, an acrid taste, and its odor is similar to that of the strobiles. It is partially soluble in water, but more so in alcohol and ether. It has a specific gravity of 0·910, becomes resinified by keeping, and is said to have a narcotic influence on the system. The water which distils over with the oil contains acetate of ammonia.

Dr. RUDOLPH WAGNER has lately published an interesting paper upon the oil of hops, and as his results are different from all hitherto obtained, a notice of them may be serviceable to the brewer. Dr. WAGNER distilled the oil from fresh hops with water. It constituted about eight per cent. of the air-dried flowers. It possessed a clear brownish-yellow color, and had a strong odor of hops, and a slightly bitter taste analogous to thyme. Its specific gravity was 0·908 at 61° Fahr. It scarcely reddened litmus paper, and was very sparingly soluble in water, requiring more than six hundred times its weight for solution. *It contained no sulphur.* The oil, rendered anhydrous by distillation over fused chloride of calcium, partly evaporates at a temperature below the boiling point of water. It begins to boil at 257°, rising to 347°, where it remains stationary for some time, and at which temperature nearly one-sixth of the clear oil distils over. The portion passing over between 347° and 437°, and constituting one-half of the oil, was also very clear, and had the odor of the crude oil. That which passed over between 437° and 455° was of a yellow color. The residue in the retort, about one-sixth of the quantity submitted to distillation, was brownish, and like turpentine. It is, therefore, evident that oil of hops is a mixture of oils. The crude oil does not give, with ammonia-silver, a metallic mirror. It is therefore not an aldehyde. When mixed with alcohol-potassa, it becomes brown, and when distilled affords alcohol, and an oil having the odor of rosemary.

After the greatest part of the oil and spirit has distilled over, a violent action takes place, hydrogen is evolved, and carbonate of potassa, mixed with a potassa salt of a volatile fatty acid, remains: the latter, when decomposed with diluted sulphuric acid, evolves an odor indicating the presence of caprylic and pelargonic acids.

From PAYEN and CHEVALLIER's analyses and report, the oil was supposed to resemble oils of mustard, asafœtida, *et cetera*, and to belong to the ethereal oils *containing sulphur; that it dissolved largely in water*, and on this account preserved the beer, and that it acted partly as the narcotic in beer and hops.

According to WAGNER the oil is isomeric with Borneo camphor, oils of cajeput and bergamot, and with the aldehyde of campholic acid. This chemist, in conjunction with Dr. BIBRA, made experiments upon animals, to ascertain whether the oil of hops acted as a narcotic; *they found it had no such action.*

The bitter principle of hops, or lupulin, may be obtained by treating the aqueous extract of lupulinic grains, combined with a little lime, with alcohol. The solution thus formed is to be evaporated, the mass treated with water, and the solution again boiled to dryness. The residue, on washing with ether, is lupulin. It is uncrystallizable, white, very bitter, soluble in twenty parts of water, very soluble in alcohol, and in ether slightly so. The aqueous solution froths on agitation, and, according to PEREIRA, gives no precipitate with tincture of galls or acetate of lead. Lupulin contains no nitrogen. It is devoid of the narcotic properties of the oil, and is said to have caused loss of appetite, and diminished digestive power, when administered in small doses.

The tannin serves, in brewing, to precipitate the nitrogenized or albuminous matter of the barley, and, therefore, assists clarification.

The resin has a golden-yellow color, becomes orange-yellow on exposure to the air, dissolves both in alcohol and ether, and is apparently the oil changed by oxidation.

A decoction of hops feebly reddens litmus, owing to free acid being present; sulphuric and tannic acids, and also lime, may be detected in it even by those who have little experience in analysis.

Dr. IVES first applied the term lupulin to the pollen, or, as it is technically denominated, *the condition* of the hop; the name has been applied since, however, to the bitter extract of the scales.

The Editor found that hops, in the usual marketable state, lose between eleven and twelve per cent when dried at 212° Fahr., and leave, on burning, from five to eight per cent. of ash.

Mr. HOLDEN obtained, on incinerating a good sample of hops, 7·708 per cent. of inorganic residue.

The drying of the hop constitutes a very important part of its management; it is performed in kilns, generally of very unscientific construction, and apparently capable of great improvement.

In Sussex, these are termed *oast-houses.* The heat imparted by the fire in drying is of great importance, and should in no instance exceed 119° or 120° Fahr.

The farina or pollen which falls through the hair-cloth, or wire, in the course of desiccation, is a valuable article, and is denominated *hop-dust.* If care is taken that no particles of fire fall into the kiln-pit, and the hop-dust be frequently removed therefrom, so as to insure its freedom from extraneous matter, it is scarcely less useful to the brewer than hops themselves. One pound of the dust is equal to four times the quantity of the strobiles. In dark-colored or common beer, a small amount might always be used without injury.

According to BRANDE, in order to give the hops a good color, they are subjected to fumigation with sulphurous acid; after this process they are packed into sacks or *pockets*, and subjected to great pressure, so as to prevent access of air, and their consequent deterioration.

Qualities.—The medicinal properties of hops are numerous. The odorous emanations arising from them possess marked narcotic properties. Hence a pillow of the cones has often been prescribed to promote sleep, in cases where the administration of opium could not be effected, or would have been objectionable. Both infusion and tincture of hops are mild and agreeable aromatic tonics. They sometimes manifest diuretic, or, when the skin is kept warm, sudorific qualities. Their sedative, soporific, and anodyne properties are very uncertain.

The lupulinic grains are aromatic and tonic, and appear to be soothing, tranquillizing, and slightly sedative and soporific. Hops have been given internally to relieve restlessness consequent upon exhaustion or fatigue, to induce sleep in the wakefulness of mania and other maladies, to calm nervous irritation, and to relieve pain in gout and rheumatism. They have also been applied, topically, in the form of a fomentation or poultice, as a resolvent or discutient in painful swellings or tumors.—*Pereira.*

The Editor does not attach much importance to the assertion that hops are narcotic, and that their influence upon the system is wonderful, especially when they are used in pillows, as he considers that the imagination plays a most important part in all such matters, —*vide* spirit-rapping, table-turning, *et cetera.*

The properties of hops in brewing are important, but may be given in few words.

All the medical qualities are to some degree exerted by the liquors in which they have been employed. They render the beer more stimulant and cordial, and the bitter principle overcomes the disagreeable sweetness arising from the malt, and which, if unneutralized, might be offensive, if not injurious, to persons having weak digestive organs.

The stimulating and strengthening qualities found in bitter beer, may be said to be owing almost entirely to the hops.

They are slightly anti-fermentive, and but for the use of them in brewing, the ale produced would soon undergo the acetous fermentation, or, in popular language, become sour.

Selection.—The flavor of the Golding or Farnham hops is rich and delicate, but the plant is one of the most tender cultivated, and the crop is uncertain. They are the heaviest, consequently possessing the greatest amount of farina or condition, and the flower is the most diminutive.

The Flemish plant produces a large flower, often three inches in length, and is considered as one of the most hardy kinds. It is productive, but of light weight, and is ill flavored.

In the districts of Kent and Sussex, the Canterbury grape, a very good and useful hop in the trade, is much cultivated.

Other varieties are produced in various parts of the country, especially in a district called North Clay, in Nottinghamshire. These hops are strong, and fit only for porter brewing, even when mellowed by age. An extract from Tizard as to the various estimates of the value of each variety may not be unacceptable.

Farnhams, he states, are in high repute, though not worth the price the brewer usually gives for them, unless the proximity of his residence be a consideration in their favor. The North Clays are rankest in taste, and fetch a better price with a certain class of buyers than those from Kent, though not generally so high as the Farnham variety. Those grown in the neighborhood of Canterbury have been much prized for their superiority, but that is not invariable. The produce of the county of Kent, though pre-eminent both for strength and flavor, differs according to soil and season, which are not always adapted to each other. The Wealds are celebrated in some of the Southern and Midland counties, but in those more north, as Cheshire and Lancashire, the Worcesters are preferred for their mildness, and for the grateful sensation they yield; some use a few Sussex or Kents with them, but most brewers in the counties just referred to, reject the growth of Kent as unpleasing to their customers.

But, however good the produce of any district may be in general, it must not be supposed that there are no bad samples of those varieties.

Such bags should be chosen as are heaviest, because it is the farina which gives weight, and hops which lose a part of it from fine weather or over-ripeness, in picking or turning on the oast, will considerably diminish in gravity.

They should feel clammy when handled, should be uniform in color, without greenish particles in the flower, and full of hard seeds, and farina or condition.

Mould may be discovered in the sample by the strig of the flower being partly bare of leaf. Particular attention must also be paid to crust, proceeding from damp or bad keeping, as it injures the quality more than age.

From the uncertainty of the seasons, the hop is an article liable to considerable fluctuations in its commercial value. The duty upon hops is twopence per pound, with five per cent. additional; this levy does not extend to Ireland. Latterly, foreign hops have been used to a considerable extent by many brewers, even in the manufacture of the finest ales; they do not, however, possess that richness of flavor so characteristic of the English growth, and hence they are never used alone, but mixed with English hops in different proportions, varying from a third to a sixth of the latter. This mixture is found to answer in a manner as well as if the entire were of home growth, especially where bitterness is required to a considerable extent, and only a moderate portion of the flavor.

The foreign hops imported into Great Britain in 1852 were 34,622 pounds, whilst in 1853 the quantity amounted to 4,739,307 pounds.

The following table shows the number of pounds weight of hops which paid duty in England during the years 1848 to 1853, inclusive, the amount of duty levied thereon, and the number of acres of land under crop, during each of these years:—

Year.	Acres.	Pounds of hops.	Amount of duty.
1848	49,232	44,343,984	£388,007 3 8
1849	42,798	16,650,914	145,693 4 9
1850	43,125	48,537,669	424,702 3 0
1851	43,242	27,042,919	236,623 1 10
1852	46,157	51,102,494	447,144 8 1¾
1853	49,367	31,751,693	277,824 16 9

BREWING.—After the foregoing details, the main subject to which they refer will now be entered upon, namely, *brewing*, and to make the matter as clear and intelligible to the reader as possible, the treatise will be divided into several heads, corresponding with the various sections of the work, as actually performed in the manufactory. These are *grinding* and *mashing; boiling*, *hopping*, and *cooling*; *fermenting*, *cleansing*, *fining*, and *storing;* in addition to which, the particular methods for making other kinds of malt beverages, besides the ales most generally consumed, will be pointed out and discussed.

It may be mentioned at the outset, that grinding, mashing, and fermenting have been referred to at some length under Alcohol and the manufacture of whisky, at page 58, *et seq.*, and therefore a full explanation of these operations will in some degree be unnecessary; but as they are performed in a manner somewhat dissimilar in this case, in conformity with a particular purpose, it will be requisite to notice them as far as they affect the preparation of beer.

Grinding.—Little, however, need be said on grinding, in addition to what has been already advanced; but were any one thing to be particularized more than another, it would be the necessity of having the natural cohesiveness of the grain destroyed in such a way, that the water may have free access to every particle of it, to insure the entire extraction of the valuable constituents. Of the various methods resorted to, whether by reducing the grain between stones in the ordinary way, or by steel mills, wherein it is cut or torn in the same manner as coffee is ground, or by crushing between rollers, that mode is preferable which disintegrates the grain completely, and loosens the husk from the fleshy parts without separating the two. A moment's consideration will show that these conditions are not fulfilled by either of the first two methods; and it is only from the use of rollers that the malt can be expected to make the nearest approach to the criterion mentioned. A secondary but important advantage is gained, by having the grain completely broken up though still adhering together; namely, the facility with which the mash is racked off, leaving only little of the extract in the grains. When it is ground fine, the matter, besides being apt to *set* and form a mucilaginous magma, retains much of the liquor, which cannot be removed except by long washing, thus rendering the worts dilute, and exposing them to the danger of acetification in the succeeding treatment. When the particles of the grains still adhere, though their natural texture is broken, each shell forms, as it were, a filter, through which the clear liquor percolates readily, leaving any matter, which might be taken up mechanically, behind. If the grain be torn or sliced, as by the metal mills, in which the available matter remains to some extent adhering to the husk in its natural state, considerable loss will be sustained, for the water will not penetrate these parts during the period usually allowed for mashing. That this is the case, is evident from the well-known fact, that dried malt will float on water for a period of twenty-four hours, without absorbing as much of the menstruum as would increase its gravity sufficiently to cause it to sink.

The annexed cuts—Figs. 156, 157—represent, in front and lateral section, the cylinder malt mill. I is a sloping trough, through which the malt passes from its bin or floor to the hopper, A, whence it is shaken between the iron rollers, B, D, working at their extremities in bearers or sockets of hard brass, fitted securely into the side frames, which are also of iron. E is a screw passing through the upright, and serving to force the bearer of one roller towards that of the other, so as to bring them nearer together when the malt is wanted in a finer state of division. G is the square end of the axis, by which one of the rollers is turned. The other rotates by means of a pair of equal-toothed wheels, H, fitted to the opposite extremities of the axes of the cylinders. *d* is a catch working into the teeth of a ratchet wheel, not shown in the engraving, on the end of the rollers. The lever, *c*, comes in contact with the trough, *b*, at the bottom of the hopper, giving it a shaking motion, which discharges the malt upon the rollers from the side sluice, *a*. *e e* are scraper-plates, the edges of which, pressing on the rollers, remove adhering matter, and thus keep them clean.

Fig. 156.

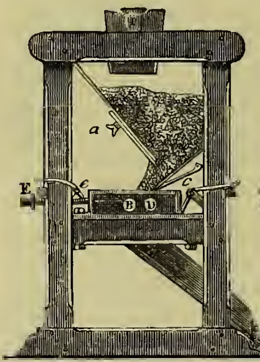
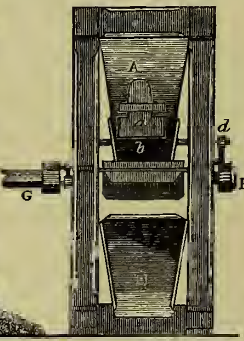


Fig. 157



When rollers are used they should be of equal size, and move with the same degree of velocity, otherwise the proper and looked-for quality will not be found in the crushed malt. Another important feature is, that the grain ought to be screened or passed through a wire sieve before it falls between the crushers, for the purpose of removing any pebbles, lest they should come against the rollers and injure them. As great inconvenience and loss may be suffered from imperfect grinding, the chief care of the brewer ought to be directed to the erection of such machinery in every department as will efficiently answer all his requirements. After the grinding, the malt is usually conducted by an endless chain of buckets to a proper receptacle placed over the mash-tub, where it remains till required.

MASHING.—To the brewer this is a subject of vital importance, and, as stated under ALCOHOL, opinions regarding its proper management are as various and as fickle among a great number as are the colors of the chameleon. These individuals generally pride themselves with the thought of having ascertained, or industriously gathered facts, bearing upon the regulation of the time, temperature, or proportion of the materials in the mash, which give them an advantage over their neighbor, and they cling with an absurd tenacity to the idea, and conduct all their operations accordingly, notwithstanding that the inutility of their mode may at once be demonstrated by a few moments' enlightened consideration. By knowing the leading properties of the materials, and their behavior with other bodies at various degrees of temperature, and the like, nothing more is required to attain perfection in the mashing, than to apportion these in a judicious and reasonable manner. An almost universal foible, if such it might be called, which influences the manufacturer is the idea, that if his methods of working were known to his brethren of the same trade, it would contribute very much to his ruin; although it will be found, upon examination, that very little difference exists between *his* particular working and that pursued by hosts of others. It generally happens that valuable discoveries result from disinterested research, or are hit upon by many at the same period, and then become in some measure generalized; but as to a manufacturer keeping any process of real worth clandestine, in order to appropriate the fruits of his study and genius, supposing it really possesses any worth, it almost invariably occurs, in the event of his doing so, that disappointment awaits him. Experiments are readily performed now-a-days, and the mind is peculiarly active in drawing deductions from known facts, which contribute to simplify the complexity of many operations; and hence it follows, that the various improvements which have taken place in every branch of art, not grounded on or corroborated by these ordeals, are seldom worthy of notice.

Wherever there is a real progression or discovery, the peculiar provision of the laws is such that it can be communicated to the world, or at least as far as the dominion of Britain extends, with greater benefit than disadvantage to the propounder, whilst, at the same time, the public derives a portion of the good arising from it, and is enlightened at comparatively trifling expense. Knowledge is disseminated in this way in a hundredfold degree, and at a fraction of the cost which would attend it if privacy and concealment were studied at every step; and the good which has arisen to society in consequence is incalculable, for instances are not wanting to show that many persons who never thought of becoming serviceable in the way of advancing art and science, upon seeing commonplace and well-known facts brought to accomplish great results, have arisen from a lethargic inactivity to strike out, as it were, by new-born talents hitherto latent, great and valuable discoveries.

Almost innumerable instances are recorded which corroborate the truth of what is here asserted, and the principle is so well understood in a purely scientific light, that the numerous books daily printed are fraught with original matter of one kind or other, which, supposing that it does not always extend to the elucidation of the topics in all their ramifications, yet what has been communicated opens the way for succeeding research, that arrives at the discovery of the object originally sought, or, by a happy digression, to that of other more valuable and interesting ends. BACON well conceived the value of being unreserved in all scientific and philosophical matters, as appears from the course he suggests; namely, that men should not be vain in publishing their knowledge, whether orally or by writing, neither should they be cunning in secreting what they have acquired, but be generous and free in communicating the facts, making them as comprehensive and as simple as possible. Were not this the directing principle, the nineteenth century would be far from possessing that enlightenment and thirst for progress manifested by all classes and grades of society, but more especially in the cycle of arts and manufactures. Looking, therefore, at the general course of things, it is evident that those who seek for knowledge with a serious and diligent spirit will not be unrewarded; the fanciful recipés of a class of ignorant men will no longer be coveted; and, in particularly applying the facts to the art of brewing, every person possessing a discriminating sense, a moderate practice in the execution of the mechanical part of his business, and a chemical manual, wherein he may learn the fundamental properties and changes which his materials possess and undergo, may cast all the supposed charms which are, or may be reputed, the ultimatum of perfection, to the wind.

It is to be understood, however, that considerable difficulty stands in the way of the brewer in the large quantity of the substances upon which he works; and the dread of failure, in the course which might be suggested as an improvement, forces him to follow the old routine of business; nevertheless, if he be fully conversant with the nature and behavior of the soluble constituents of his malt, reason will place a wholesome restraint upon him from running to extremes which would be fatal, and will direct him in the intermediate course, wherein the success and security from loss are to be found. A knowledge of the materials will again be productive of the happiest results, when the ever-varying state of the atmosphere is most unpropitious; for by it he will be able to make such modifications as will effectually counteract acetification, his direst enemy, which invades him with the first rays of the summer's sun, and hovers over the building, waiting to gain an entrance at every opening which want of attention in the mashing, cooling, or fermenting of the worts, or any uncleanliness in the utensils, in the shape of albuminous or mucilaginous matter undergoing the acid phase of fermentation, might afford. Many instances could be cited, were it deemed necessary, of the complete loss of the whole of the goods at different stages of the work—some in the mashing, when, instead of a clear concentrated extract, a small quantity of a mawkish amylaceous liquid had been obtained, which readily entered into the acetous fermentation, and, instead of yielding an agreeable, grateful, and wholesome beer, nothing was found but vinegar; meanwhile the remainder of the valuable materials of the malt lay enveloped, or *locked up*, by the impenetrable folds of mucilaginous matter, caused by the application of a high temperature in the mash water. Often the infection of acidity is caught up during the cooling; sometimes the fermentation completely fails.

In speaking of the mashing, and pointing out the manner in which it is, or ought to be, conducted by the brewer, it is necessary that the reader should recur to what has been said of this operation, and the *rationale* that was given, explanatory of the changes that take place in the transformation of the starch into sugar, under Alcohol, at page 61, for the same remarks apply to the process as conducted in the brewer's tun.

There is no doubt that some improvements are yet to be effected in the extraction of malt, notwithstanding that many very specious advancements have been made in this direction, which, in a greater or less degree, have been found serviceable in increasing the quantity of matter in the wort, or protecting the goods from the destructive action of acidity.

Before stating the particular operations of mashing, it may be well to make a few allusions to the quantity of extractive matter usually obtained from malt, and the problem of its thorough exhaustion, a point which is the grand aim of mashing. From the analyses given of malt, as well as those of barley, it will be seen that the available constituents of the former amount to 78·3 per cent. when dried by the ordinary means; and as a quarter of good malt generally weighs three hundred and fifty-two pounds, it follows that 275·5 pounds of these are available valuable matter, the remainder being water and husk. It is to be borne in mind that all this quantity is not saccharine matter, but that there exists in it a variable proportion of albumen and gluten; these, however, are abstracted to a great extent in the mashing, and are afterwards removed, as will be seen further on. Now, the best practical results average about ninety to ninety-five pounds, as shown by the barrel gravity saccharometers, per quarter; but, as every unit of this number equals 2·6, or, according to DRING and FAGE, and CASARTELLI, 2·7 pounds of real extract, it is evident that the total of the valuable ingredients is 234 to 249 pounds; for 90 × 2·6 = 234; and 95 × 2·6

= 249; but, if the calculation be made according to the latter authorities, the produce will be 243 and 256·5 pounds.

It is, however, easy for the brewer to ascertain when he is successful in his exhaustions, and also what ought to remain after fermentation to give body to his product. It will be well, also, to be able to find the amount of extract in a wort from the gravity of the liquor, as indicated by the saccharometer, without the necessity of recurring to the tables, or sliding rules accompanying them; for it frequently happens that errors creep into such calculations, and the results they point to are sometimes greater, sometimes less, than the real amount contained in the worts: to do this, all that is required is to multiply the indication by 2·6, or 2·618—2·7, according to CASARTELLI—and the product will be the real weight of extract in each barrel of the wort.

By this means the total extract per quarter in the first mash may be found, and, by deducting it from 275·5, the remainder is what is left in the grains to be extracted in the next mash; knowing this, the liquor employed may be regulated accordingly, so as to obtain a dense wort, and thereby avoid the danger of acetification, to which dilute worts expose the products. In addition to these advantages, the director has the great satisfaction of performing his work methodically, and as one who is master of his business.

As to the nature of the change that takes place in the mash-tun, and the circumstances which induce it, enough has been said upon this point under Acetic acid and Alcohol to throw light upon the metamorphosis of the starch, and other bodies of an analogous composition, into sugar, as will be found, it is expected, sufficiently explicit to satisfy the desire of every brewer; but as acetic acid and alcohol are of a different nature from the article now considered, so the modification of those principles, although their ultimate effects are the same in the three instances, requires in this case special discussion.

It is the object of the vinegar-maker to obtain a wort of such strength, or containing as much saccharine matter, as will give a product affording, after the fermentation and oxidation of the alcohol, about five per cent. of acetic acid,—of the distiller to extract the valuable principles entirely, and produce a menstruum which subsequently will completely ferment, leaving as little of the saccharum as possible latent in the liquor; but the brewer's course is different from these, inasmuch as *he* wishes a dense extract, not to acetify, nor, at the same time, to be wholly converted into alcohol, but to preserve it from the former, and restrict the latter to such a degree as will merely cause the formation of sufficient spirit to communicate a pleasant hilarity to those partaking of it, reserving the greater portion of the goods for communicating to it richness, unctuousness, and flavor; and if he leaves these particulars, or any one of them, unattended to, his beverage will very quickly be distasteful to his customers.

From these differences in the operations of the three classes of manufacturers, whose art borders upon the same principle—that of the exhaustion of the malt and the conversion of the extractive matters into sugar—it will be plain to every one, that there must be a marked difference between the course followed by each; the peculiarities of the brewer's methods will therefore engage attention for the present.

The first important point with the brewer is the complete abstraction of the saccharine and amylaceous substances in his malt; and next to this, but not less important, is, that he is to effect it with the smallest possible quantity of liquor, it being understood that he must be rigorously careful to prevent any acidification. Six or seven barrels of water per quarter of malt are generally sufficient for the exhaustion; of which two and a quarter to three and a quarter barrels are lost in the after operations of boiling and fermenting before the products are of good quality. The manner of applying the liquid seems to have an important bearing upon the result, as is evident from the very great proportion which is proved to be useless, by being expelled afterwards in different stages of the manufacture.

Now, the question naturally suggests itself—Why is this liquor employed in the mashing in the first instance? and then, Can the great waste be obviated, and the expense incurred by the brewer in supplying fuel and other necessaries in order to concentrate his worts, be saved?

The Editor thinks that much requires to be attended to in this particular; and it appears so practicable, that it is surprising it should have been overlooked by those brewers and chemists who have treated the subject, while they continue to instruct in the old method. It is plain that the diastase and gluten of the malt are capable of transforming a much larger quantity of starch into sugar than what is present, and it is no less obvious that the water employed is sufficient to hold in solution a far greater proportion of the saccharine substance than it can possibly meet with in any brewing operation; it therefore follows that the methods adopted are defective, inasmuch as an unnecessarily large quantity of fluid is used to attain the results, which, according to the known properties of the constituents, might be accomplished with less. Some steps have already been taken in this direction by Mr. TIZARD, in introducing an improved mode of mashing by means of his attemperator, and also in his treatment of the hops; nevertheless, it seems that a great deal has yet to be accomplished before the brewer can arrive at that perfection in his art which is so very desirable. It is well known that the diastase of the malt is most active when the liquid is rather dilute, and the temperature is between 160° and 170° Fahr.; but as the latter might be injurious at the outset in a brewing operation, the former, and even 165°, could be supplied with safety. Hence it is apparent, that by sustaining an equalized temperature, and with the use of a moderately large quantity of water, the conversion of the starch into glucose will be complete, and that it can be almost entirely extracted in the first solution, leaving nothing in the first mash for the subsequent sparging, but to wash out that portion imbibed by the grains. By accomplishing this with four to five barrels, instead of six to seven, the brewer would derive material advantage, as the *lengths* which are at present employed, and subsequently expelled by evaporation, *et cetera*—a process that entails a loss of time and money—would to a great extent be unnecessary. Another inducement to the adoption of means for obtaining dense worts, is one which brewers must necessarily value, namely, the production of sound beer; for it is impossible to brew a good beverage from an inferior wort; and, when the latter is weak, the tendency to acetification is far greater than if a heavy extract were operated upon.

Considerations like these ought to be sufficient for those whose practice it is to vary, in almost every case, the manner of mashing, now applying a low temperature, then a high one, but always using repeated mashings, which entail the trouble of continued boiling afterwards, and ultimately impair the quality of their goods.

The chief point is to apply as much water, and maintain such an initial temperature, as will, on sufficient time being allowed, completely disintegrate the grains at one mashing, and leave nothing for the subsequent abstractions but what remains of the first in their pores. This is the highest perfection in mashing, and whatever may be adduced by bookmakers and particular persons, upon modifications of working, and the application of high or low degrees of temperature, it would be well if the intelligent brewer would study how far such instructions are likely to operate in favor of the criterion here laid down before he embraces them.

Having spoken of the principles of mashing as fully as the subject requires, the usual routine of the process will now be entered upon.

The first great point to be attained in a brewery is, scrupulous cleanliness, particularly in the various vessels, lest any albuminous or amylaceous substances should be left adhering to them, and which, by entering into a putrescent fermentation, would communicate the same to the worts, and prove highly detrimental. It is hoped that the importance of this requirement is so well understood, that it will be unnecessary to dwell further upon it; still, its being overlooked would ruin an establishment, even if every other particular were carefully attended to, and managed with consummate skill and ability. The only means of securing this point are to wash the various backs, boilers, coolers, and other utensils, occasionally with lime-water, made by macerating a bushel of quicklime in about twenty barrels of water—otherwise to have all the utensils made of metal; it would be desirable, also, to retain any backs, or other vessels which may not be constantly in use, full of water, till such time as they are needed. The manager should be likewise careful to keep the mash-tun perfectly clean; for if any grains should remain in it after a previous brewing, their albuminous contents might suffer decomposition, and give rise to, or induce, an acid fermentation, which, if absorbed, would prove destructive in the succeeding brewing. Too much precaution cannot be used in guarding against these causes of mischief, which, though apparently trifling in themselves, operate so as to render the brewer liable to a heavy loss, by giving rise to those ruinous decompositions to which allusion has been made.

Unless the brewer mashes every day, it would be well that he should make all the preliminaries required for the proper execution of his task on the day of brewing; the coppers should be charged with liquor, and fuel sufficient to sustain the fire for heating the materials should be provided; where the mashing is performed daily, these requirements are secured as a matter of course.

The work, on the day of brewing, should be vigorously proceeded with as early as possible, and especially in hot weather, which demands on the part of the operator greater vigilance and care to secure his success.

It is customary to have a journal, wherein the temperature of the atmosphere, the quantity of malt, the heats of the different mashings, as well as of the tap, and other particulars, are recorded; and this, besides being always necessary, to show the business habits of the foreman, very often leads to some improvements, when several operations are afterwards studiously considered and their results compared.

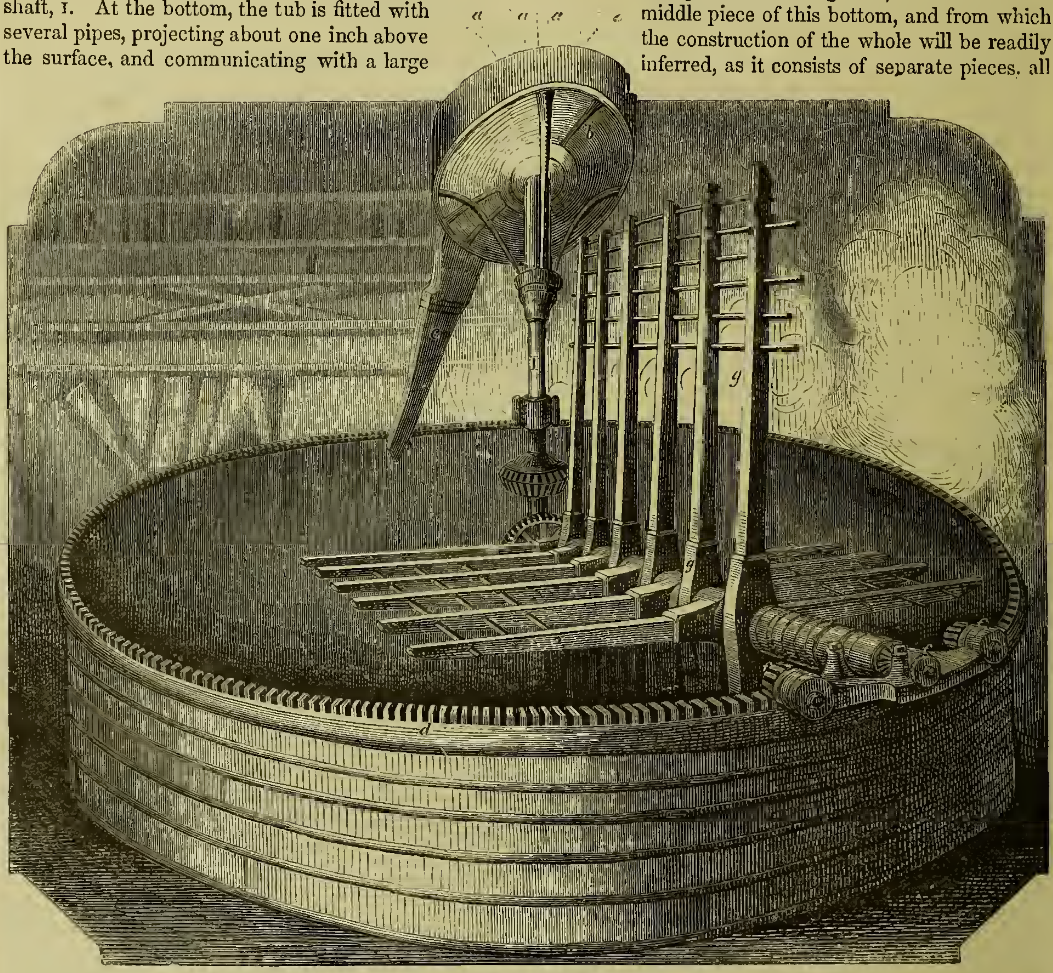
The malt, of whatever description it may be, should be ground, if possible, the day previous to mashing, or, at most, it should not be retained longer than three or four days crushed before it is submitted to the mash-tun; for, if kept a long time, it will attract moisture from the atmosphere, become heated, through the effects of an internal decomposition of the saccharine substance, and render the beverage of a bad quality.

The ground malt is usually conducted, in well-regulated breweries, by an Archimedean screw to the hoppers over the tun in the mashing-room, which serve as magazines for it, and whence it is let into the latter, when fit, and macerated with water. There are two modes of accomplishing this mixture—one by manual labor, and the other by machinery; but the latter is preferable on all occasions, as it is much more effectual in breaking up the masses of malt which are apt to form in the water. Indeed, very often serious injuries arise from the *balling* of the malt, when the mashing has been carelessly performed with oars, or too large a quantity of water has been run upon it at first; for, besides being wasted, by enveloping a certain volume of air, and being but partially wetted, and surrounded by an elevated temperature, the agglomerated portions very quickly generate acetic acid, if not timely prevented, by being broken up with proper machinery.

The mash-tun and its appendages, which are always subjects of importance in the brewery, will here be described. The illustration presented is copied from the large tun in use at Messrs. ALLSOPP and SONS, of Burton-on-Trent, and by Dr. BÖTTINGER kindly supplied to the Editor.

Fig. 158 represents this tun fitted up with very ingenious and effective machinery for mixing the malt and water thoroughly. The hopper, to which reference has been already made, is not seen in the drawing, but it is placed on strong wooden bearers immediately above the mash-tun, and is connected by four shoots, *a*, to the so-called feeder, *b*, which is elongated into a narrow trunk, *c*. The tub itself has the enormous dimensions of twenty-one feet diameter, and is six feet deep; it is mounted with a toothed rail, *d*, into which the cogs of a small wheel, *f*, at the end of the stirring or mashing apparatus, *g*, fit; this mashing machine consists of a strong iron shaft, to which a number of wooden rakes is attached; it has a double motion, one upon its axis, and the other round the tun, both being communicated by the central shaft, I. At the bottom, the tub is fitted with several pipes, projecting about one inch above the surface, and communicating with a large one below; they serve to conduct the liquor to the under-back or receiving vessel. Above this bottom is the filtering or straining apparatus, consisting of a false bottom of wood, perforated with a large number of minute holes, countersunk in the lower side, as represented in Fig. 159, which shows the middle piece of this bottom, and from which the construction of the whole will be readily inferred, as it consists of separate pieces, all closely fitting together, and supported by bearers, which raise the false about two inches above the true bottom.

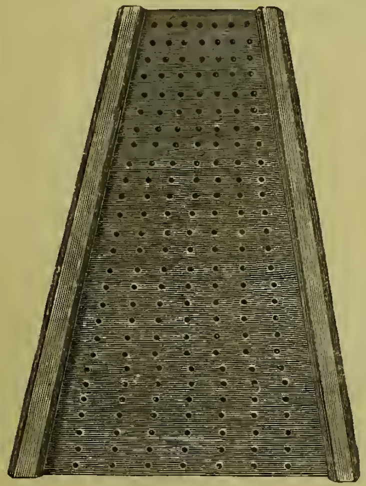
Fig. 158.



On mashing, the water, at a high temperature, is first let into the tub, and when the latter and its adjuncts have attained a moderate degree of heat, by abstracting caloric from the liquid, which reduces it to the proper mashing point, the malt is added from the hopper through the feeder; motion is then communicated to the machine, and the contents kept in brisk agitation till the mixing is completed. When this is done, the tub is carefully covered down, to preserve the heat of the mash, and exclude the air from the wort as much as possible. After about two hours' rest in this state, it is drawn off to the copper; an operation which must be performed with great care, to insure the liquor being perfectly bright, and free from any solid particles of malt. At this stage the sweet liquor is apt to enter upon the vinous fermentation, and thence to pass to the acetic, to prevent which the temperature is raised to ebullition, and the hops added; meantime the partly exhausted malt, after the whole of the liquor has been drawn, is to be subjected to a second operation. For this purpose the tub is uncovered, and a fresh quantity of water, the amount of which is regulated according to the density of the first worts, or the quantity of the matter yet unextracted, but which will be afterwards referred to, is turned on at the proper heat, and mashed by the machine, as in the foregoing instance; the tub is then covered, and the whole allowed to digest for one hour, or less, according to circumstances, and then drawn off as before. By proper attention, the whole of the requisite constituents of the malt should be taken up by these two mashings; sometimes, when the mash is very stiff, a third sparge is let in upon the grist to exhaust it, but the product is used only for *table beer*.

Having, in this short sketch of the mash-tun and its operations, given an outline of the whole course of mashing, a few remarks in explanation of the process will now be added. It will be seen that—as is the custom with a great many—the water is let into the tun at a higher degree of heat than is required by the mash, allowing it to cool down to the proper temperature before the introduction of the malt. Others, again, admit the malt and heated water simultaneously, while the machine, being put in motion, mixes them thoroughly. In the latter instance, it is plain that the heat of the liquor must be much higher than the initial heat at which the constituents of the malt should be extracted, namely 160°, or bordering upon it; for the caloric of the water is communicated to the mash-tun, as likewise to the goods, and from these causes a decrease of 20° or 30°, or more, is observed, according to the state of the weather; and it is equally obvious that the mixing of the malt and a liquor of 180° or 190°, is unadvisable; for although, in the event of mixing them, a mean temperature of 158° or 160° may result, yet the starch, albuminous, and glutinous part, cannot but be rendered insoluble in those portions with which the solution comes in contact at the commencement.

Fig. 159.



On the contrary, if the water be poured in at 170°, or under the mean, after fifteen or twenty minutes it will be far below that at which the diastase and gluten are most active in converting the starch into glucose. The conclusions from these observations evidently favor the heating of the mash-tun with the water, and when it has been reduced to 165°, or between this and 170°, to admit the malt from the hopper, and mash rapidly. In this case the malt is the only body which is to abstract the heat, and the slight elevation of the temperature supplied for meeting this decrease does not react so injuriously upon the goods as in the first case.

Others, again, turn on as much water at a low degree of heat as will moisten the malt completely, and cause it to swell, after which, the remaining quantity of water required to make up the wort is let on at 190° to 194°, and mashed in the usual way. This method is said to be advantageous—first, by lessening the tendency to set, and secondly, by giving the diastase greater scope for acting upon the starch, as the per centage of sugar is dissolved out in the first wetting, and the residual portion is more permeable to the solution, which, having about 165° as its mean, is very effective in exhausting the goods.

It should be remembered, however, that diastase is very soluble, and that it is wholly, or to a great extent, removed with the sugar, leaving only the gluten in proximity with the starch to effect its solution. During the subsequent part of the operation, when the water of a higher temperature is poured on, many authorities of long experience affirm that the particles of this active principle are placed at such a distance from the starch, that the diastase cannot exert the same influence as if it and the starch were exhausted at the same time. The quantity of water which is usually taken, varies from one and a half to two and a half barrels per quarter of grist for the first mash, according to the system of working followed by particular persons; but if the mean temperature could be sustained throughout the mashing, it is quite evident that one barrel, six firkins, which weighs about 630 pounds, would be even more than sufficient to exhaust the quarter of malt of its soluble ingredients, consisting principally of glucose or saccharine matter, which requires only 1·33 parts of water in the cold for its solution, but much less will suffice when the temperature is raised as in mashing.

From all these peculiarities, it seems that the general defect of mashing lies either in not extracting the whole of the goods, in consequence of the gluten and portions of the starch of the grain forming a gelatinous mass which envelopes the starch and sugar, and does not allow the water to flow off in consequence of too elevated a temperature; or the starch may indeed be carried off in suspension, but owing to the low temperature it is not converted into glucose, and in the subsequent operations this kind of wort is prone to acidify and spoil, particularly if the time of mashing and tapping be long. It is evident that the maintenance of a due degree of heat, and the employment of the proper amount of liquid so as to have a dense wort, are the two chief points which must arrest the brewer's attention; and if he could surmount all the difficulties arising from long custom, based upon imperfectly understood principles, and make the attempt to add science to his working practice, it is evident that a considerable part, if not all the loss which is at present so generally sustained by brewers, might be converted into profit. The usual method of mashing, by letting the water into the tun at an elevated temperature, and then the malt, or both simultaneously, so that by their admixture a medium temperature may be attained, does not answer all the requirements which are wanted, since the application and distribution of the heat is at the first glance partial and unequal; besides, it readily passes off by radiation and conduction, leaving the mash at such a temperature as cannot exert the desirable influence upon the conversion of starch into sugar. The only contrivance worthy of notice, which has been introduced for the purpose of obviating this disadvantage, is that patented by Mr. TIZARD of London, and known as the *mashing attemperator*. This apparatus serves the double purpose of masher and attemperator at the same time, and there is no doubt that it is productive of the good effects which it professes to accomplish, since it can be so managed to preserve the heat at any temperature which may be deemed most suitable, and for an indefinite time, should it be required. The heating medium is completely under the control of the operator, and therefore he can urge or restrain it within certain limits, even to a nicety.

The influence of the attemperator, in communicating a temperature of 160° to 165° Fahr. to the goods during the mashing, is highly beneficial, inasmuch as the whole of the starch is saccharified, and most probably a portion of the mucilage which is formed during the malting. Hence its great advantage at once appears palpable; and, consequently, deserving of the brewer's attention. In the absence of the attemperator, the best course for the ordinary brewer is to use only as much liquor as will moisten the malt, and then apply the remainder so as to maintain the heat of the mash at 160° or 165° during the mashing.

The time usually devoted to this operation has been mentioned, at page 252, as being two hours after the water has been thoroughly incorporated with the malt, which generally happens in about twenty minutes, when the quantity of malt is small; when a large bulk of goods is operated upon, the mashing takes from a half to one hour, but this is not the case with a great many brewers. The following table relating to the temperature and time of the standing of the mash, *et cetera*, is taken from LEVESQUE, and throws considerable light on this point. It should be remarked, however, that the heat of the mash-water varies according to the malt employed, that for pale malt being the lowest, whilst for high-colored it may be poured on at a much more elevated temperature.

Temperature of the air at mashing.	CLASS I. Heat of the mash 146° to 148°.	Time of standing of the mash.	Temperature of the air at mashing.	CLASS II. Heat of the mash 145° to 147°.		Time of standing of the mash.	Temperature of the air at mashing.	CLASS III Heat of the mash 144° to 146°.		Time of standing of the mash.	Temperature of the air at mashing.	CLASS IV. Heat of the mash 143° to 145°.		Time of standing of the mash.
	Firkins per quarter 6.	h. m.		Firkins per quarter 7.	Firkins per quarter 8.	h. m.		Firkins per quarter 9.	Firkins per quarter 10.	h. m.		Firkins per quarter 11.	Firkins per quarter 12.	h. m.
10°	197·00	4·00	10°	189·00	184·00	3·00	10°	178·00	175·00	2·00	10°	172·00	170·00	1·00
15	195·17	4·00	15	187·42	182·59	3·00	15	176·84	173·92	2·00	15	171·00	169·19	1·00
20	193·34	4·00	20	185·84	181·18	3·00	20	175·68	172·84	2·00	20	170·00	168·28	1·00
25	191·51	4·00	25	184·26	179·77	3·00	25	174·52	171·76	2·00	25	169·00	167·37	1·00
30	189·68	4·00	30	182·68	178·36	3·00	30	173·36	170·68	2·00	30	168·00	166·46	1·00
35	187·85	4·00	35	180·10	176·95	3·00	35	172·20	169·60	2·00	35	167·00	165·55	1·00
40	186·02	4·00	40	179·52	175·54	3·00	40	171·04	168·52	2·00	40	166·00	164·64	1·00
45	184·19	4·00	45	177·94	174·13	3·00	45	169·88	167·44	2·00	45	165·00	163·73	1·00
50	182·36	4·00	50	176·36	172·72	3·00	50	168·72	166.36	2·00	50	164·00	162·82	1·00
55	180·53	4·00	55	174·78	171·31	3·00	55	167·56	165·28	2·00	55	163·00	161·91	1·00
60	178·70	3·40	60	173·20	169·90	2·45	60	166·40	164·20	1·50	60	162·00	161·10	0·55
65	176·87	3·20	65	171·62	168·49	2·30	65	165·24	163·12	1·40	65	161·00	160·19	0·50
70	175·04	3·00	70	170·04	167·07	2·15	70	164·08	162·04	1·30	70	160·00	159·28	0·45
Heat of the tap from 144° to 146°.			Heat of the tap from 143° to 145°.				Heat of the tap from 142° to 144°.				Heat of the tap from 141° to 143°.			

In the first column under each class of this table, the temperature of the atmosphere at the time of mashing is noted; the next columns are the degrees at which the water should stand to bring the mash to the points at the head of the columns, and the figures at the foot specify the temperature at which the tap stands.

Mashing in this way often causes much variation in the results, owing to the dryness or particular quality of the malt, and the state of the atmosphere. When very dry malt is used, on mixing it with water of a certain heat, the resulting temperature is not an arithmetical mean of the two, but is somewhat higher, owing to an elevation of a few degrees, caused by the conversion of starch into sugar, and its solution in water; for invariably chemical decompositions and combinations give rise to heat, and this fact should be kept in mind when adding the water for the mash, and its temperature regulated accordingly. As an example of the first, the action of sulphuric acid on alcohol might be cited, and of the second instance, the effect produced when this acid is added to water; in both cases, considerable elevation of heat is indicated. Were there no development of heat, the temperature would be under the mean of the substances, in consequence of the amount of caloric which the malt takes up, without giving the same indication by the thermometer as water under a like influence; it happens, however, that, when mixed, there is a rise which, when working upon a small scale, is not very material, but if a large body of goods be operated upon, so as to retain the heat, this elevation is considerable; and if not carefully observed, or the original points proportioned thereto, it may be the cause of setting the goods, and of much loss and injury.

When barley is mixed with twice its volume of water, the heat arising from this mixture will be about the mean temperature; but if pale malt be similarly treated, the result will exceed the mean; and if highly dried brown malt be taken, the thermometer will indicate a rise of 40° over the mean: this elevation always takes place in the first mash, during which the conversion of the starch proceeds with the greatest activity. Such results do not, however, always attend the mixing of the water and malt, as, when the latter has stood some time after grinding, it absorbs water from the atmosphere and becomes *mellowed*, in which case the development of the heat is not so great as when the goods are perfectly dry; hence, when mashing such mellowed malt, the liquor ought to be somewhat hotter than is used with the fresh.

Another circumstance which influences the heat of the mash is the bulk of materials taken; thus, it is evident that the temperature, when only two barrels of water per quarter are employed, must be higher than if three were taken, notwithstanding that the rise by mixing is greater in the first instance; both give off an equal amount of caloric to the tun; but as in the latter instance there is more of the substance, it contains more heat collectively than the former, and therefore it is not reduced so much by the abstraction.

DONOVAN, speaking of the temperature to be employed in mashing, lays down the following as a general rule:—For well-dried pale malt, provided the atmosphere does not exceed 50° Fahr., the heat of the first mash-water may be, but should never exceed, 170°; that of the second, 180°; and for the third, 185°, but never beyond.

It may be observed that the danger of acetification of dense worts at a temperature of 160° Fahr., is not incurred by a slight prolongation of the time of mashing and setting, as might be at first apprehended, for both are unfavorable to the change; this will be clearly seen on referring to the article on ACETIC ACID and VINEGAR, at page 7. Now, if the agitation of the goods by the machine be continued only for a short time, from half an hour to an hour, the question might be asked, will the conversion of the starch be completed during that time? Again, during the subsidence of the grains and other matters distributed through the liquor by the mashing, will the whole of the starch become saccharified? The answers to these questions might with truth be in the negative; and the conclusion forces itself upon the reader, that the shortness of the time of mashing, and the ineffectual methods adopted for maintaining a suitable temperature, are the chief causes which operate *against* the obtaining of dense worts, and in favor of acetification. This is evident to every brewer who takes the trouble to examine the subject rationally: allowing that the mashing is successful in discharging the whole of the starch and other valuable matters from the grain, and that nothing is left in the shell—which, however, is not so—on the suspension of the motion of the machine the chief part of the starch remains, as is well known, unacted upon; and as the grains fall to the bottom, they carry considerable portions of the goods with them out of the reach of the solution, and the increased gravity of the liquors, in consequence of the portion of glucose that is formed, also precipitates and hastens the descent of the yet unconverted starch, leaving in a short time the upper part of the liquid clear, and of a very low density. Certainly, the quantity of wort imbibed by the grains assists in the change into sugar, but the transformation is not nearly so effectual as if the contents were disseminated through the bulk of liquid taken for the mash. Another consideration which tends to show that the prolonging of the mash, provided the due degree of heat is kept up, as by TIZARD'S attemperator, would not cause the time of *setting the tap* to extend beyond the usual period allowed in the generality of breweries, is, that the chief part of the starch being saccharified whilst the liquid is in agitation, the time afterwards necessary for the clearing of the wort would not be so long as in the present instance; for the grains, the sinking of which is to be effected, being dense and in large masses, would readily subside, and the delay caused by the minute particles of starch still floating in the liquor towards the bottom would be avoided. These strictures may appear to the brewer at variance with his preconceived views; still the Editor feels assured that, by due care, the course which he recommends would prove effectual, since the principle on which it is based is conformable to the well-known law which regulates the solution of matter.

Having thus far spoken of the data and principles that ought to regulate mashing at this stage of the process—for the first mash is the most important—the method of drawing off the wort, or *setting the tap*, as it is called, together with the extraction of the portion of the goods still retained in the grains by the operation of sparging, or after-mashing, will next be considered.

In reference to the setting of the tap, LEVESQUE very justly remarks that the goods should be drawn off at the same degree as is indicated at the conclusion of the mashing, and recommends the adoption of the plan without incurring any risk of hurtful decompositions taking place, whatever the variety of malt worked upon. Those who may not be very conversant with the real nature of the subject, and may have doubts as to the quality of the malt—its newness, hardness, weight, slackness, or dryness, all of which require a variation of the heat, or of the quantity of liquor—if they are already acquainted with the final heat of the first mash of a good operation, they have only to raise the tap to this point, and copy it in their subsequent mashings.

From the great necessity which exists of governing the heat of liquids, it is evident that the thermometer must come into general request, as, by its use, acidity, arising from a low, and setting from an excessive heat, may be entirely prevented.

The thermometers of the usual make, with or without a case and reservoir, offer some difficulty in this respect; because, as TIZARD asserts, when the case and reservoir are affixed, the progressive heat of the mash is conveyed too slowly to be of accurate use; and on the other hand, with an exposed bulb, the mercury drops so instantaneously on its removal from the mash, and with such rapidity, especially at high temperatures, that before the grains can be wiped off the scale, and the vision of the operator has penetrated the cloud of steam, and the film of mucilaginous or other matters adhering to the glass which intervenes, the slender column of mercury cannot be discerned till it will have fallen many degrees below the real heat of the mash. Apart from these great inconveniences, there is also the probability of the instrument being broken by the action of the machine. At best, the mere dipping of a thermometer into the goods is so unsatisfactory, and so hazardous in its applications, that its indication might lead to the setting of the whole mash. To remedy these obstacles, TIZARD attaches to the back of his attemperating machine two movable brackets, reaching midway between the centre and side of the mash-tun, the extremities of which are provided with sockets. Into these sockets a long thermometer is dropped, having a scale which stands above the surface of the mash, and a little lamp attached. In this way the instrument travels with the machine, and the index, from being illuminated, will show truthfully the heat of the mash, and any variation as it occurs. Similar contrivances might be adopted in brewing with the ordinary mashing machines, at little expense ; and it is needless to say that the guarantee which would thus be given for knowing the exact temperature, would, when compared with the system usually resorted to, be of incalculable service.

The first mash being completed, and the under-back wherein the sweet worts are received being thoroughly clean, the tap is turned on gently at first, and afterwards more quickly, till the liquor runs half bore. Unless great care be exercised, the worts will not flow off bright and clear as they should do, and particles of the more finely divided grain, which are sometimes productive of inconvenience in the succeeding operations, will percolate.

If the process has been successful, the wort will be of the same shade of color as the malt employed; it should have a tough and close head of a silvery whiteness, and passing, when examined in the vessel, to a delicate cream on the surface, full, effervescing, and fine flavored, considerably more so than the succeeding extract, in consequence of the more mucilaginous and resinous parts of the grist not being abstracted. When the heat of the mash is too high, it is observed that the silvery white head has a tinge of brown, and this color will be deeper in proportion to the greater elevation of the mash above the proper degree. Again, if the heat be low, the characteristics of the head do not appear, neither is it so close, firm, bright, or lively in flavor. In very low heats the head will not stand, but fly off instantly, and the taps will be thick and muddy; this kind of wort, on being exposed to the air, will readily enter into decomposition and turn acid.

When the whole of the extract has been drained off, the quantity of liquor to be used in removing the residuary portion, retained mechanically by the grist, as well as any starch which may still be present, is turned on, and if the preceding details be attended to, the quantity of the starch will be found to be very inconsiderable. Many persons employ from three-eighths to one-half the quantity of water taken from the first extract, and add it at 185°, or 10° over that at which the first mash is made, and treat the goods similarly to what was done at the commencement, except that the time extends only to a quarter or one-half that granted to the first. The same precautions should be observed in setting the tap as have been already mentioned, and the worts conveyed to the boiler with the first portion.

By an economical disposal of the temperature and duration of the mash, as well as the proportion of the liquor taken, the residual starch in the grains will be inappreciable ; but when, as in many cases, the operations are conducted in an uncouth, unscientific, and often in an irrational way, there remains after the second mash as much as from eight to ten pounds per barrel extract, and it even happens that it is not wholly removed by the third watering. This product, however, is coarse and ill-flavored, owing to the great proportion of bitter resin and mucilage intermixed with it, and which hitherto remained in the grains, the temperature not being retained at that degree at which the diastase and gluten could exert their combined influence in saccharizing these substances. In order to avoid the accumulation of such degenerating constituents in the third and fourth mash, the opinion of Levesque is, that the heat should be 10° to 12° higher in the second than in the first mash, if products are run into the boiler as the strong wort; if three mashings are to be made for the same, he says a difference of 5° or 6° in each is most suitable, making the final one at 160°.

It will be observed, that all these customs of mashing so repeatedly are at variance with the principles inculcated by the Editor, and which he believes to be just in all their details, and certain to result in success, if a little exertion were made on the part of the operator; it is also his opinion, that when the activity of diastase and gluten is maintained during the mashing by contact with the constituents at the proper degree of heat, considerable portions of the gum or mucilage are transformed into sugar; and hence their presence would not be found to such an extent in the final sparging as when the old process is followed. In a scientific point of view, the conversion of gum into glucose is an ascertained fact; and the method of accomplishing this conversion differs in nothing from the course adopted on the Continent for manufacturing sugar from starch—namely, boiling with very dilute sulphuric acid. On the same grounds, the catalytic action of diastase and gluten should, theoretically, transform the mucilage, or gum of the malt, into grape sugar as effectually as it does the starch; for these two substances are of analogous composition, and maintain that analogy with grape sugar, as will be observed from the annexed formulæ, showing the composition of the three bodies:—

Gum, anhydrous,....................	$C_{12} H_{11} O_{11}$
Starch, anhydrous,..................	$C_{12} H_{10} O_{10}$
Grape sugar, anhydrous,............	$C_{12} H_{12} O_{12}$
Grape sugar, hydrated,.............	$C_{12} H_{14} O_{14}$

From this it is plain that the only difference in the elementary composition of the three substances is, that gum contains one, and anhydrous grape sugar two equivalents of water more than the starch, and that the change of the other two into sugar involves no greater complexity of action than the assimilation of a few equivalents of hydrogen and oxygen; but, in doing this, the whole atomic constituents may arrange themselves differently, though still retaining the relative elementary proportion to the other constituents existing in either starch or gum.

Before leaving this subject, it may be stated as certain, that the change of the gum into saccharum is much less active than that of the starch, and hence it requires the proximity of the saccharifying agent in the malt, and the intervention of a continued heat at the proper pitch, before it is completed. From this circumstance arises the great value of Mr. Tizard's apparatus, as it maintains the contents of the mash tun at the most efficient degree of heat throughout the mashing.

There is another method followed for abstracting the residuary matters in the grist, after the first mash is completed, which is called *sparging*, from the circumstance that the liquid is sprinkled on the goods from numerous outlets. It is said to be very beneficial in its results, particularly when the whole of the wort is intended for the strong or the better quality of beer. The method of sparging is as follows:—When the tap has been set for drawing off the first wort, the hot liquor, of the same temperature as the preceding mash, is sprinkled on from a machine constructed thus: a perforated tube is taken and laid upon a bar, the whole being placed horizontally in the tun, and rested upon a pin in the centre, and over which a receiving vessel is placed to supply the tube with water. The perforations extend to the whole length of the two or three arms of the tube, so that the liquid flows out horizontally, but in opposite directions; and through the effect of the force of this efflux, together with the centrifugal motion communicated by the current coming from the receiving vessel, the pipe is kept rotating, and the liquor is dispersed equally over the goods. Some, instead of the tube, use a cover, which they place over the liquor, and direct the stream upon it; the first method seems, however, to be more efficient.

Many persons do not set the sparger till one-fourth, one-half, or even three-fourths, of the strong extract is drawn off; but when the liquid is sprinkled on gently—as it must be from the perforated tubes—there need be no apprehension of the wort being diluted; and the good which it does, by displacing the quantity of the stronger mash imbibed by the malt, as also by exhausting the grist of the residual saccharum, without taking up the resinous constituents, is an undoubted recommendation; besides, when the chief part of the first mash is drawn off before the sparging, the grains accumulate in a denser layer on the bottom, and the facility with which it is desirable that the edulcoration should penetrate every portion of the grist, cannot be turned to advantage. The mashing attemperator already alluded to, has perforated tubes attached to it, so that water can be transmitted through them over the mash.

To those whose routine of working is based on old established practice, this mode may appear ruinous, as their after mashings contain six to ten pounds of extract per barrel, which are calculated to be as valuable as an equal proportion of the first wort; but, without stopping to inquire whether this is the case or not, it may be sufficient to assert, on the grounds which it is hoped have been clearly explained in the foregoing, that, if a proper course of mashing be adopted, there will be none of this matter—the whole of the valuable constituent will be taken up in the first wort, and what remains of it embedded in the grist, removed by the washing or sparging, in the manner which has just been described. A dense and valuable wort will be thus obtained, and the subsequent concentration—as will be explained under the Boiling, in the next stage—the time expended, and the danger of decomposition, to which the extraction of weak and impure goods subjects the operator, are entirely obviated.

It is necessary to have the sparging continued without intermission, till the whole of the soluble matters is removed, using only as much liquor as is necessary to make up the proper lengths.

The grains left after mashing—see analysis, page 244—or when the whole of the starch has been removed, are very beneficial for the use of swine and cattle, as they contain gum, and some of the nitrogenous or protein constituents of the barley, in the shape of gluten, together with a certain amount of cellulose, which is valuable and as effective in nourishing as an equivalent weight of the original unmalted grain. In addition to these, if the methods recommended in the mashing have been attended to, there will be a further quantity of mucilage, which will contribute, in the animal economy, to effect the same purposes and ends as starch.

SACCHAROMETRY.—Before dwelling circumstantially on the *boiling*, *hopping*, and *cooling*, it will be desirable to make some further allusion to the methods at the brewer's command for taking the density, and for making himself acquainted with the amount of matter in his wort, as well at the high temperature at which it is drawn off from the under-back, as when he reduces it in the refrigerator. The knowledge of the gravity of the product after fermentation, so as to ascertain the quantity of spirit and saccharine matters contained in it, is of importance to every brewer.

Reference has been made, at page 250, to the means whereby the worts may be tested, and their content of saccharine matter ascertained, either from the specific gravity or by the saccharometer; but as the liquor at this stage is usually between 150° and 160° Fahr., the indication which it gives is only the apparent density, since, by expansion, the bulk of the solution is considerably increased; and, therefore, the amount of solid extractive matter, in any given volume of the liquor, is much less than what the same bulk would show at 60°, the barometer being at 29·5 or 30 inches.

The saccharometers chiefly employed are those of ALLAN, BATE, DRING and FAGE, and LONG. The first three are recommended by the Excise; but, as ALLAN'S has been discarded, the instruments of BATE, and DRING and FAGE, are solely used by the Government. BATE'S is usually made of metal, has five floats answering to the different strengths of the wort, and one to indicate which of the poises will suit on every occasion, mostly on the same plan as SYKES' alcoholometer, described at page 132. The instrument is accompanied by a book, wherein are copious explanations and directions for using it, together with sixteen pages of tables of gravity and strengths per barrel, containing over 40,000 figures, in 10,000 distinct determinations, calculated to answer every degree of specific gravity, from ·995 to 1·150, as also every alternate degree of temperature, from 50° to 150° Fahr. Notwithstanding all this labor and diversity of numbers, TIZARD says that it is scarcely possible to look down a double column of degrees and results, especially towards the right, and not discover great irregularity in the deductions.

He points this out in respect to the conclusions of the two hydrometers recommended by Government, in the quantity of extract in the gallon and barrel of wort, of the same gravity, as follows :—

Specific gravity by the saccharometer.	Quantity of solid extract in pounds.				Excisable difference in each barrel.
	In each gallon.		In each barrel.		
	Allan.	Bate.	Allan.	Bate.	
1001	0·0293	0·026	1·0656	0·936	0·119
1010	0·2997	0·258	10·7890	9·288	1·501
1015	0·4517	0·387	16·2600	13·932	2·328
1100	3·2638	2·593	117·4840	93·448	24·036
1150	5·1182	3·903	184·2540	140·508	43·746

The wide discrepancy of these results speaks loudly against ALLAN'S, assuming that BATE is right; but the forementioned gentleman is far from this opinion, and justly so, if it be considered that the expansion of the volume of liquor, by the increased saccharine extract, is *regular*, and in an *even ratio;* for, instead of the results being so many multiples of the factor laid down for the gravity 1001, it will be observed that they are considerably under, without the content in any way accounting for it.

The instrument of DRING and FAGE is more simple than the foregoing, as it has but two weights, corresponding to worts containing twenty and forty pounds per barrel. It is constructed of brass, and is similar in shape to a glass hydrometer, except that the stem whereon the indices are engraved is square, and marked on three sides: the first, from 1 to 20; the second, from 20 to 40; and the third, from 40 to 60. No weight need be used till the wort exceeds twenty pounds per barrel; after this, the weight No. 1 is slipped on at the top, and the indications observed on the side of the stem, marked No. 2, till the figure 40 is exposed, and lastly, the weight No. 2 is placed on, and the value sought on the side marked No. 3, till it reaches 60, which is the limit of the instrument.

Mr. LONG, of London, is the maker of another saccharometer, said to be very exact, but which is not recognized by the Government; it has one accompanying poise, to be used when the wort exceeds twenty-five pounds per barrel. This instrument is based and regulated on the assumption, that a wort marking twenty pounds per barrel on the instrument, contains fifty-two pounds of real extract; and, taking the weight of a gallon of such saccharine matter to be 1625, water being 1000, the preceding quantity occupies 3·2 gallons, leaving 32·8 as the space occupied by the water, and hence the volume, or decimal part of a gallon, filled by each pound, is 0·6154. Dispensing with the rigid accuracy which analytical chemistry teaches, and viewing these results in a commercial and business-like manner, where truth and despatch, without very scrupulous exactness, are the requirements, the conclusions of LONG are worthy of being received, as they lead to the estimation of the saccharum with some degree of certainty.

TIZARD, by a series of calculations upon the same basis as those of LONG, arrived at results somewhat different, and which are tabulated by him, as annexed, showing, by comparison, the discrepancy between them and the numbers given by the makers of the most popular instruments :—

Specific gravity.	Weight of solid extract to the imperial gallon.				
	Allan.	Dring and Fage.	Bate.	Long.	Tizard.
1010	0·2997	0·2777	0·258	0·2583	0·2618
1020	0·6053	0·5555	0·516	0·5194	0·5236
1030	0·9168	0·8333	0·775	0·7777	0·7854
1040	1·2343	1·1111	1·033	1·0388	1·0472
1050	1·5577	1·3888	1·293	1·3000	1·3090
1060	1·8870	1·6666	1·552	1·5583	1·5708
1070	2·2223	1·9444	1·812	1·8194	1·8326
1080	2·5634	2·2222	2·071	2·0777	2·0944
1090	2·9105	2·5000	2·332	2·3388	2·3562
1100	3·2636	2·7777	2·593	2·6000	2·6180
1110	3·6226	3·0555	2·854	2·8583	2·8798
1120	3·9875	3·3333	3·116	3·1194	3·1416
1130	4·3584	3·6111	3·378	3·3777	3·4034
1140	4·7352	3·8888	3·640	3·6388	3·6652
1150	5·1182	4·1666	3·903	3·9000	3·9270

It may be remarked that the products of TIZARD are higher than those of BATE and LONG; their being multiples of the factor ·2618 may be easily seen to have resulted from the circumstance that they are calculations, whereas in the other statements, if experiments were resorted to, to corroborate calculations, the inequalities might have arisen from various relative causes; by their aid, however, the quantity of extract in a wort may be pretty accurately ascertained, and when the brewer knows theoretically what he is to expect, and is, besides, able to make the calculation, without blindly trusting to tables, provided he multiplies the gravity indicated by the saccharometer into ·2618, the product will be the pounds of saccharum per barrel.

Dr. URE, who in 1830 experimented on this subject, states that the specific gravity of the solid dry extract of malt is 1·264, and the specific volume 0·7911, that is, ten pounds of it will occupy the volume of 7·911 of water. When this extract is dissolved in its own weight of water, the density of the resulting liquid, by calculation, ought to be 1·1166, whereas, by experiment, it proved to be 1·216, thus showing that a considerable condensation of volume had taken place in the act of combination with the water.

The following table, showing the relation between the specific gravity of the solutions of malt extract and the quantity of matter they contain, illustrates the above :—

Malt extract. Water.	Malt extract in 100.	Sugar in 100.	Specific gravity.
600 + 600	50·00	47·00	1·2160
600 + 900	40·00	37·00	1·1670
600 + 1200	33·33	31·50	1·1350
600 + 1500	28·57	26·75	1·1130
600 + 1800	25·00	24·00	1·1000

Regarding the saccharometric tables constructed by BATE and others on solutions of sugar, and not upon those of extract of malt, URE remarks that they agree pretty well with the former, but differ materially from the latter; ALLAN'S tables, he says, give the amount of a certain form of solid saccharine matter extracted from malt, and dried at 175° Fahr.; but he found it impossible to make a solid extract of solutions of malt, except at much higher temperatures; further, he asserts that the extract upon which ALLAN operated was by no means dry; for at 1·100 gravity, he assigns 29·669 per cent. of solid matter, whereas only twenty-five per cent. is present; and again, at 1·135 per cent., he states 40, when it is only 33·33.

Apart from the foregoing consideration, there is another important circumstance which must be taken into account in ascertaining the gravity—namely, the different expansions of bodies at various degrees of temperature, from 32° to their boiling point. When many liquids are heated from 32°, or their point of greatest density, to 212°, considerable difference is observed in this respect; for instance, the dilatation of alcohol is much greater than that of water, and this again than mercury, and so of numerous other liquids. The amount of expansion of different liquids in passing through 180°, that is, from 32° to 212° Fahrenheit, is found by experiment to be—

Alcohol, ...	$\frac{1}{9}$	Oil of turpentine, ...	$\frac{1}{14}$
Nitric acid, ...	$\frac{1}{9}$	Sulphuric acid,...........	$\frac{1}{17}$
Fixed oils, ...	$\frac{1}{12}$	Water,........................	$\frac{1}{23}$
Ether,........................	$\frac{1}{14}$	Mercury,....................	$\frac{1}{55}$

It may be well to illustrate the meaning of the above, by showing the difference in volume of water from 32° to 212°, as given by several chemists who have investigated the subject.

There is one remark, however, which is deserving of being made, for the sake of those who may not be conversant with such subjects—namely, that heat communicated to the bottom of liquids is readily diffused through the whole body; not, however, by radiation, as is the case with solids, but by the dilatation of the inferior particles, which renders them specifically lighter than those above them, on which account they ascend, their place being occupied by other globules; these, again, receiving warmth and ascending like the preceding. Thus, by the constant exposure of fresh portions of water to heat, and the motion produced in the liquor by their rarefaction, the whole bulk is brought to that degree beyond which any application of more heat would destroy the limits within which the density and liquidity remain, and the fluid would become aeriform. It is plain, then, that it is gravitation which exerts such great influence on the transmission of caloric through a body of liquid, as well from the facts above cited, as from its tardy absorption by the solution when the heat is applied to its surface, in which case the supernatant particles only receive the rays by which they are rendered lighter and continue to float upon the denser. This slowness of acquiring heat from the surface led RUMFORD to deny that water, or fluids generally, had any power of conducting it; still it is long since known that liquids do conduct heat, though in a ratio far inferior to solids.

Science has converted this phenomenon to highly beneficial uses in many departments of industrial progress. The thermometer, with all its inestimable benefits, is based upon it, and at the present day, the application of expanding substances to the requirements of manufactures, trade, and navigation, commands no small consideration in contributing to the wealth of nations.

According to KOPP, water expands when heated from 32° to 212°, 0·042986 of its volume, as will be seen from the annexed table of the expansion of water from the freezing to the boiling temperature, the volume at 0° C., or 32° Fahr., being taken as unity:—

Temp. Cent.	Temp. Fahr.	Volume.	Temp. Cent.	Temp. Fahr.	Volume.
0°	32°	1·000000	21°	69·8°	1·001776
1	33·8	0·999947	22	71·6	1·001995
2	35·6	0·999908	23	73·4	1·002225
3	37·4	0·999885	24	75·2	1·002465
4	39·2	0·999877	25	77·0	1·002715
5	41·0	0·999883	30	86·0	1·004064
6	42·8	0·999903	35	95·0	1·005697
7	44·6	0·999938	40	104	1·007531
8	46·4	0·999986	45	113	1·009541
9	48·2	1·000048	50	122	1·011766
10	50·0	1·000124	55	131	1·014100
11	51·8	1·000213	60	140	1·016590
12	53·6	1·000314	65	149	1·019302
13	55·4	1·000429	70	158	1·022246
14	57·2	1·000556	75	167	1·025440
15	59·0	1·000695	80	176	1·028581
16	60·8	1·000846	85	185	1·031894
17	62·6	1·001010	90	194	1·035397
18	64·4	1·001184	95	203	1·039094
19	66·2	1·001370	100	212	1·042986
20	68·0	1·001567			

The preceding table shows the degree of contraction which water undergoes when heated from 32° to its point of greatest density, which is stated as 39·2° Fahr. From this point to the normal temperature of 60°, the expansion of a volume of water is 0·000894, and from this to 158°, ·021475 of its original volume. Now, a given bulk of liquid, having solid bodies, such as mineral salts, *et cetera*, dissolved in it, does not increase or contract in the same proportion when heated from 32° to 212°, as pure water, in consequence of the solid matter not being so expansible as the liquid, and hence it follows that dense worts will not dilate or contract as much as those which are more dilute. On examining worts of high temperatures, the object is to find the increase of weight consequent upon the contraction of any given bulk of liquid, when cooled from a higher to a lower degree of heat.

According to BATE'S tables, the allowance which should be made for every ten degrees between the normal points, 60° and 150°, is as follows:—

Saccharometric gravity.	70°	80°	90°	100°	110°	120°	130°	140°	150°	Sum.
10	1·0	1·2	1·5	1·7	1·9	2·1	2·3	2·5	2·8	17·0
50	1·2	1·4	1·6	1·8	2·1	2·3	2·5	2·7	3·0	18·6
100	1·4	1·6	1·8	2·0	2·2	2·5	2·7	2·9	3·2	20·3
150	1·6	1·8	2·0	2·2	2·4	2·7	2·9	3·2	3·4	22·2

The subjoined table, selected from those of BATE by TIZARD, will answer the purposes of the ordinary brewer; and where the corresponding degree does not occur, a correct fraction may be attached at an average, founded on the following facts. When a liquid, the specific gravity of which is 1000 at 60°, is heated to 78°, the instrument will sink two divisions below the true gravity as found at 60°, and if the temperature be elevated to 93°, it will sink four divisions, and so on; in other words, any liquid heated to these points, and tested with the hydrometer or saccharometer, will manifest a much higher density when cooled down to 60° Fahr.; thus, if there be three liquids at the temperatures of 124°, 92°, and 78°, and the instrument be dropped into them, it will sink in the first ten, in the second eight, and in the third six divisions, lower than it would in the same were they cooled down to 60°; hence, when testing the liquors heated to these degrees, it is necessary to add the numbers ten, eight, six, *et cetera*, to the apparent densities, in order to find the real gravity at the standard of 60° Fahr.

Specific gravity at 60° Fahr.	Apparent gravities giving the same density at the accompanying heats as the first column at 60°.									
	Ap gr.	Degrees.	Ap. gr.	Degrees.	Ap. gr.	Degrees.	Ap. gr.	Degrees.	Ap. gr.	Degrees.
1000	998	79·00°	996	93·00°	994	105·00°	992	115·50°	990	125·20°
1010	1008	78·00	1006	92·00	1004	104·00	1002	114·50	1000	124·00
1020	1018	78·00	1016	91·33	1014	103·00	1012	113·50	1010	122·80
1030	1028	77·33	1026	90·66	1024	102·50	1022	112·50	1020	122·00
1040	1038	76·66	1036	90·00	1034	101·50	1032	111·50	1030	120·80
1050	1048	76·00	1046	89·33	1044	100·66	1042	111·00	1040	120·00
1060	1058	76·00	1056	88·66	1054	100·00	1052	110·00	1050	118·80
1070	1068	75·33	1066	88·00	1064	99·00	1062	109·00	1060	118·00
1080	1078	74·66	1076	87·33	1074	98·00	1072	108·00	1070	116·80
1090	1088	74·66	1086	86·66	1084	97·50	1082	107·00	1080	116·00
1100	1098	74·00	1096	86·00	1094	96·50	1092	106·50	1090	114·80
1110	1108	74·00	1106	85·50	1104	96·00	1102	105·50	1100	114·00
1120	1118	73·50	1116	85·00	1114	95·50	1112	104·50	1110	113·20
1130	1128	73·33	1126	84·50	1124	94·50	1122	104·00	1120	112·40
1140	1138	73·00	1136	84·00	1134	94·00	1132	103·20	1130	111·40
1150	1148	72·66	1146	83·50	1144	93·50	1142	104·40	1140	110·80

The following theorem, for reducing the gravities of hot worts, is taken from TIZARD *on brewing:*—To unity, or 1, representing the par or standard of water, add 0·1 for every twenty-five points of gravity indicated by the instrument, and 0·01 for each degree of temperature above 60, and multiply the sum by ten times the latter number for the correction.

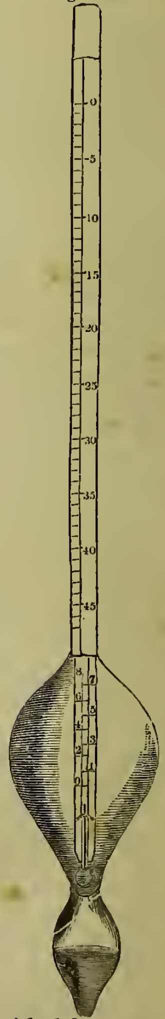
Example 1.—Let the apparent density be 6, and the temperature 92°, then $(1 + {\cdot}32) \times 3{\cdot}2 = 4{\cdot}224$, which, added to the original 6, gives 10·224.

Example 2.—Apparent gravity 27, temperature 124°.

Here $(1{\cdot}1 + {\cdot}64) \times 6{\cdot}4 = 1{\cdot}74 \times 6{\cdot}4 = 11{\cdot}136$, and $11{\cdot}136 + 27 = 38{\cdot}136$, results which agree with those of BATE.

Before leaving this subject, it may be well to notice a new saccharometer, constructed by Mr. J. CASARTELLI, of Liverpool and Manchester, on the principle of that of DRING and FAGE. It is made of glass, of the shape of the ordinary hydrometer, as sketched in the annexed—Fig. 160—except that in the large bulb a small thermometer is placed to register the temperature of the liquor. The stem of the saccharometer is graduated by a scale from 0 to 55, denoting so many pounds per barrel of extractive matter, and the plate affixed to the thermometer is engraved with figures 0 to 8, the former corresponding to 60°, and the latter to 157° Fahr., each of which represents one division of the stem, as the liquor at these respective temperatures would, if cooled to 60°, exactly mark an extra degree to what it shows. The manner of using it is as follows:—Having floated it till the level of the liquor is stationary, the indication is noted; the instrument is then taken out, and the figure to which the mercury has risen in the small thermometer observed and added to the preceding; the total will be the number of pounds of extractive matter in a barrel of the wort or gyle at 60°. This ingenious contrivance, besides being as correct as the instruments of DRING and FAGE, is much more simple, so that there is no need of sliding rules and thermometers, as furnished with other instruments. On the whole it is much preferable to those of metal, and although it is more fragile, yet it is not liable to lead to the wrong results which the others are apt to produce when disfigured by dinges, *et cetera*. The factor used in the instrument is 2·72, and the proportion of alcohol which the wort would yield on being fermented, is tabulated in a card accompanying it.

Fig. 160.



BOILING THE WORTS.—In order to show the chemistry of this operation, the first consideration is the composition of the worts, when drawn off from the mash-tun to the underback, and the manner in which they are affected by the boiling.

Firstly, then, from the views and detailed facts given under the mashing, it will be seen that the wort is composed of water, saccharum or glucose, mucilage or gum, generated by the heat applied in drying the malt, and some small quantities of starch, albumen, and gluten. According to the greater or less care bestowed on the preceding operations of malting and mashing, the wort will vary in its content of saccharine extract. If a wort be evaporated at a moderately elevated temperature without approaching ebullition, and the residue heated in a water or air bath, or in vacuo over sulphuric acid, to expel the last trace of moisture, every hundred parts of the dry substance will yield generally from ninety-two to ninety-four per cent. of sugar, four of gum and a bitter resinous matter, and two of albumen, gluten, and inorganic salts. The composition, however, must vary much, according to the mode adopted in the making of the malt. Most of these matters, except the sugar, may well be dispensed with in the finished beer; for they injure, rather than improve, the quality of the product.

The gluten is insoluble in water; but, in consequence of the presence of glucose and diastase—to the latter of which it in some measure assimilates in transforming the starch into sugar—it is dissolved in the mashing. The gum is soluble in the wort, as is also the albumen, excepting at a temperature approaching ebullition, when it coagulates into clots or flakes; this substance is also insoluble in alcohol, which precipitates it from its solutions.

It has been observed that the gluten of the malt, during the mashing, undergoes a change, by which lactic acid is to some extent formed. The cause of this alteration—which is rather injurious to brewing, owing to acetic acid very often resulting—is found in an incipient fermentation, whereby the casein of the crude gluten is transformed into lactic acid and other peculiar products, which change is also communicated to a portion of the starch. Boiling of the worts is avowedly practised with the intent of removing the excess of nitrogenous matter; for, if this were permitted to remain, it would undergo the putrid fermentation, and completely destroy the whole product; boiling is reputed also to give to the liquor a grateful flavor, and render it more wholesome; but the most satisfactory recommendations in its favor are, that it diminishes the liability to *acescency*, by expelling the contained air; and those matters that are subject to change, being in a measure excluded from the atmosphere, which is absolutely necessary for acetification taking place, the liquor remains sound for a long time. Boiling is resorted to for other purposes—namely, the expulsion of the excess of liquor used in the mashing, as well as for the transformation of any starch which might still remain intact into saccharum or dextrin. Attention to the principles of mashing, and the use of the attemperator, would do away with these disadvantages. There is another important object for which the worts are boiled, namely, the extraction of the valuable and medicinal principles of the hops, whereby the flavor of the liquor is improved, as well by the agreeableness of the volatile oil of the flowers, as by the bitter resin and tannin, which are dissolved out, and which destroy the luscious sickly taste of the saccharum of the worts. Besides, hops impart not only a bitter aromatic taste, but also a keeping quality, as they counteract the natural tendency of the beer to become acerb; an effect partly attributable to the precipitation of the albumen and starch by their resin and tannic acid, and partly to the antifermentable properties of their lupulin and other constituents.

Various opinions have been set forth regarding the necessity, the efficacy, and the injuriousness of boiling; generally speaking, the idea is, that from the manner in which it is usually conducted, it acts prejudicially, inasmuch as by it the most prized material of the hops—the odoriferous oil—is dissipated, and too much of the disagreeable principle and tannin extracted, whereby the bitterness and astringency become too powerful. Those who condemn boiling altogether should study its antiputrescent effects, especially where albuminous and other substances, such as casein, fibrin, *et cetera*, analogous to those in the extract, are present. Boiling has the effect of expelling air from the interstices of the particles of the liquid, and coagulating the albumen; and, by keeping the matter excluded from air or oxygen, it may be preserved without undergoing putrefaction. It is well known that nitrogenous substances, which are otherwise very readily decomposed into products of putrefaction, may be retained for a considerable period in a wholesome state, by expelling air, and keeping them afterwards in exhausted receivers. Cold effects the same thing, notwithstanding that the contact of the air is permitted; but then the main condition which induces the chemical combination of the elements of the body with the oxygen—namely, an elevated temperature—is wanting. By abstracting the air contained in the wort, and guarding against its reabsorption by keeping the liquor in exhausted vessels, it may be preserved during any length of time without giving rise to acid products, or by retaining it at a low degree of cold, its purity is not affected; but, upon the application of a heat ranging from 70° to 90°, with exposure to the influence of the air, the oxidation of the compounds present follows, and finally acetic acid, with the products usually formed in putrefying bodies, results.

Were there only saccharine matter present, the liquor might be preserved a length of time at any temperature, without danger from the acidity to which worts are so subject; but the proneness of the nitrogenous impurities to *eremacausis*, opens the way for the mucilage and sugar to pass partly into the lactic, and partly into the vinous fermentation, and then, by a further state of chemical decomposition, into acetic acid, and, it is needless to say, the whole materials are spoiled.

Thus far, in reference to the keeping of the worts, and their protection from decomposition, by boiling; its immediate effect will now be taken into account.

Evidently this operation tends to, or has for its object, the removal of albumen and any other matters which, if permitted to remain in the wort, would readily absorb oxygen on being left in contact with the air, and cause the chemical changes which brewers have so much reason to apprehend; but, in effecting this purpose, it is argued that, besides a valuable portion of the saccharum being abstracted, the essential oil of the malt is almost entirely volatilized, in consequence of the long boiling at the high temperature at which this is done. That portions of the sugar are removed, or rendered unavailable to some extent, cannot be doubted; for it is well known that when vegetal extracts, and most organic compounds, some of which are as permanent in their nature as sugar, are boiled for a long time, a gelatinous substance, similar in character to woody fibre, forms in the solution at the expense of a portion of the compound, which must have suffered decomposition. Such is the case in the open copper of the brewer, especially when the air is not excluded; but as to the oil inherent in the malt being dissipated, this is a new and gratuitous supposition which has no foundation; for the oil of the grain in its natural state is not expelled at a temperature of 212°, being enveloped by the substance, and it is well known that the volatile oil, which causes so much inconvenience to the distiller in vitiating the quality of his spirit towards the end of distillation, is generated during fermentation, as will be explained afterwards.

From what has been said, it is evident, as the correct conclusion to be drawn, that were it not for the purpose of removing the nitrogenous matters, the boiling of the worts might be dispensed with. It has been urged that distillers do not boil their worts, and yet the attenuation in the succeeding fermentation becomes most complete. This must be granted; but it should be borne in mind that they immediately remove the spirit from the gross nitrogenous products by distillation, lest the latter, if permitted to remain with it, should change it into acetic acid, by regular and well-defined laws, which have been already discussed at page 4 *et seq.* It is true, also, that the generation of alcohol in the liquor during fermentation, and the protracted way in which this is carried out in some varieties of ale breweries, would, in the first instance, cause the precipitation of the albumen and mucilage; but portions of the gluten might still remain, and though its quantity might be apparently insignificant, yet, under the various effects of temperature and other causes, it would prove destructive, if not removed either during the fermentation, in the shape of yeast; or before fermentation, by boiling; or altogether excluded by a better system of mashing. In the latter instances, however, it could not be expected that the gluten would be displaced; and as the boiling does not wholly separate it, the chief effect is to be sought in the fermentation; but the hurried manner in which this is usually performed in this country, is not at all consonant with the theoretical principles which might be adduced by the chemist as calculated to guarantee success.

It is evident, however, that the boiling of the worts liberates some, though not the whole, of this albuminous body as is supposed; for the formation of yeast afterwards in the fermenting tun, is owing to the nitrogenous matters entering into combination with oxygen, derived either from the water or sugar of the liquid. Now, if the boiling were wholly discarded, it is a question whether the excess of these substances would not prove destructive to the beverage, especially if retained for any length of time, or exported to warm climates, as, from their complexity of composition, the affinity which unites the elements together cannot be so powerful as to counteract their tendency to pass into simpler and more permanent bodies.

The latest analyses of albumen lead to the empirical formula, $C_{216} N_{27} S_2 H_{169} O_{68}$, besides earthy and alkaline phosphates, without which it cannot exist; but how these are arranged is unknown.

Putrefying albumen yields, among other products, sulphide of hydrogen and sulphide of ammonium.

When oxidized by sulphuric acid and peroxide of manganese, or bichromate of potassa, it yields oil of bitter almonds, benzoic acid, various aldehydes, hydrocyanic acid, cyanide of methyl, *et cetera*, besides other products not yet investigated, by the study of which its very complex construction will be unravelled.

It is well known among brewers, if not in theory at least in effect, that beers retaining much nitrogenous substances, however richly they may be hopped and otherwise carefully prepared, cannot be preserved in warm climates; neither will they retain their qualities at home when, on tapping, the air gets access to them, unless the temperature of the atmosphere be about 45° Fahr. or lower; for as soon as the air is admitted, if the temperature is above 60° or 70°, the oxidation of the gluten commences, and the heat rises in consequence; the commotion produced causes the formation of a further quantity of alcohol from the sugar, and changes the alcohol already formed into acetic acid.

Were the fermentation of the worts carried on at a low temperature, as in Bavaria, then the excess of the albuminous and other analogous bodies might be allowed to remain, without the least inconvenience in the way of causing putrefaction, so as to terminate in acetification, and there would be no need of removing any portion of them by the preparatory operation of boiling.

Many brewers allege that their only reason for boiling is the extraction of the lupulin of the hop, and to effect this the ebullition is continued at no small expense and trouble for a considerable period; but this view is not entitled to much credit, assuming the truth of the preceding remarks on the subject. Others, on the contrary, denounce boiling as being, next to acetic acid, the bane of the brewery; but reason affirms, and time and experience attest, that there is a mean which affords security from the bad effects of either extreme.

Albumen is insoluble in water at a temperature approaching ebullition, and the expansion of the air caused by the imbibition of the heat dissipates it as soon as it reaches 212° Fahr.; the further continuation of the heat after this point is gained, must evidently have in view the agglutination of the finely-divided insoluble particles already precipitated; but to prolong it more than fifteen minutes seems unreasonable, and is certainly prejudicial, inasmuch as portions of the saccharine matter will be decomposed, as before stated. The criterion which appears to regulate the time of the boiling in breweries, is the formation of a mass of insoluble or precipitated matter; but the great object should be the coagulation of the particles, and their falling to the bottom in the copper should not be so much regarded, for, during the fermentation, whilst the yet soluble portion of gluten is becoming insoluble in the form of yeast, these will be carried away mechanically in the eviscerated matter, or deposited during the cleansing, without proving injurious to the liquor.

From these considerations it follows, that the worts should not be subjected to a protracted ebullition, with the view of removing the albuminous ingredient, it being sufficient merely to render it insoluble in the menstruum; and whether it remains in the copper, is retained in the hop-back, or passes along to the fermenting tun, to be there finally and entirely removed with the barm, is a matter of no very great moment, since it is deprived of the possibility of decomposing by oxidation within this period.

These observations refer solely to the action of boiling on the wort singly, and now the effect of boiling on the hop will be considered.

It will be observed, from the notice already taken of the hop, that its efficacy as to flavor and bitterness depends upon the volatile aromatic oil which it contains, and the resin which is abstracted; it likewise communicates astringency, in consequence of the tannic acid, or tannin which it yields. The gum and other matters removed from the flowers by water are of no very great interest. Essential oils in general are dissipated by a temperature of 212°, notwithstanding that their boiling point is considerably above this standard. If hops be macerated with water and subjected to distillation, the whole, or chief portion, of the oil will very readily pass over into the receiver, leaving the solution in the retort almost entirely destitute of aroma, but retaining the bitterness and astringency in a very marked degree. This is well known to brewers generally; and those who show some regard to facts, curtail in practice the time of boiling, or make such deviations from the old-established routine, as seem to them best adapted for the retention of the aroma. It was with this view that the close boiler was introduced, and that a reservoir or tank, through which the steam from the wort was conveyed, was subsequently placed in connection with it, for the avowed purpose of catching the oil of the hop in its flight, and using the water thus impregnated in the succeeding brewings; yet the inefficiency of this arrangement might have been readily understood, by simply consulting a chemical manual, or any one conversant with such matters; for the boiling to which such worts were submitted, acted in direct opposition to the object of retaining the volatile oil.

Were the *condition* or valuable portion of the hop extracted in such a way as to retain the volatile aromatic oil, there is no doubt the beer would be greatly improved in quality. TIZARD has made an effort in this direction, by introducing his *hop-converter*, as it is termed; by the use of which, he says, the most agreeable constituents are abstracted for the better kinds of ale, and, if it be deemed necessary, the coarser portions may be used up in the inferior products. His method of doing this is by converting the lower part of the under-back into a hop-back, by inserting a perforated floor above the true bottom of the mash-tun. Upon the solid bottom of this new hop-back, or above it, but beneath the perforated plates, coils of tubing are laid, through which steam from an adjacent boiler is forced, and for facility of management there should be a steam-cock, fixed in the entrance pipe to regulate the flow of vapor. The hops, after being thoroughly broken up, are laid evenly upon the perforated floor of the hop-converter, four hours before setting the tap, and as much hot water poured upon them from the heated liquor-back as will effect their saturation completely; they are then left to digest for one hour, after which the steam is passed through the convoluted pipe till the mixture has attained a temperature of 200° Fahr., retaining it at this point for the remainder of the time, till the setting of the tap. The steam is then turned off, and the wort let in upon the hops to the depth of six inches, when the pump is worked, and the goods discharged upon the coolers, taking the precaution to preserve the depth of six inches of liquor upon the hops during the time of racking and sparging. In this way, the patentee asserts, the value of the hop is retained; for the temperature during the digestion being 12° below the boiling point, very little vapor is expelled; but as it serves to withdraw the whole of the valuable constituents, and the worts are in contact with the hops during the exhaustion of the grist with the hot liquor—all the taps being open—the whole of their extract and essence is carried off in the goods.

In operating thus, it will be observed that TIZARD discards boiling the worts, but this is in some measure compensated by raising the heat of the mash towards the time of drawing off the wort to a temperature of 200° or upwards, by means of his attemperator, for the purpose of coagulating the albumen, and maintaining this degree for twenty minutes, or half an hour, as may seem best. Were the whole of the starch already converted into sugar, there is little doubt but that a method of steam boiling would be most suitable and economical; and as to the means of hopping, could the whole of the lupulin be extracted by it, the operation would be decidedly preferable to the system of boiling under high pressure for one, two, or more hours, now almost universally followed. Steam boiling also supplants the several costly requisites which enter into the brewer's stock of apparatus and material, and thus effects a saving in the plant, while the work performed will, by proper management, be as effectual, and more satisfactory, than when accomplished by the various coppers and furnaces.

Other contrivances have of late been resorted to for dispensing with boiling the worts and hops together, to obviate the danger of losing the aromatic constituents. Among these, the patent of NEWTON, of London, may be instanced; this gentleman prepares the extract from the hops, and then disposes of it to the brewer.

The same method has been followed for some time in France and some parts of the Continent, but the brewers in the United Kingdom do not appear to appreciate it. NEWTON'S mode of preparing the extract is as follows:—After having dried the hops at a low heat till they become so brittle as to be easily pulverized, the powder is passed through a coarse sieve for the purpose of retaining any stalks or pieces of wood which might be accidentally present; it is then put into a close vessel, and strong spirit of wine or alcohol poured over it till the whole becomes charged; this mixture is allowed to repose for twenty-four hours, after which the alcoholic tincture is drawn off into an appropriate receiver, and the residual powder washed as long as any extract is obtained.

The next course is to distil off the alcohol, by which means the oil and resinous body are left, mixed with a little water, which is also dispersed, first on the sand-bath, and finally on the water-bath. The aqueous washings of the powdered leaves, which contain almost the whole of the resin, are also evaporated till the water is expelled; and when this is accomplished, and while the resinous matter is still warm, the oily body procured from the alcoholic tincture is added, and intimately mixed with it. Such is the humulin of the patent processes, one pound of which is said to be as efficacious as three pounds of flowers. By adopting any of these methods, the waste of wort occasioned by the absorption of the hops would be avoided, and the products would in every respect be superior to what can be produced by boiling hops and wort together. The humulin could be added to the worts either after they are boiled—whether by steam or furnace heat, but previous to their being run on to the cooling or refrigerating backs—or before fermentation, as the case may be.

The brewer may suspect that the introduction of humulin is, like many other modern innovations, a mere deception, not designed for his advantage, but solely for the good of the parties who have an immediate interest in recommending it. He ought not, however, to be blinded to his own interest by such suspicions, especially if the benefit attributed to any suggested improvement is easily tested; but if it appears to be a plausible process, and not inconsistent with the testimony of scientific men, he should give it a fair trial, not pronouncing condemnation upon it before he has allowed himself an opportunity of forming a judgment on its merits.

Some well-informed men in the trade are of opinion, that without a continuous system of boiling the constituents of the hops cannot be entirely extracted. Were this really the case, the practice of boiling might be modified, and the present boiler—to which reference will be immediately made—converted into a digester, wherein the worts and hops might be heated to any desired point by means of high-pressure steam, and maintained at any eligible degree, for one, two, or more hours, till the extractive matter of the hop would be obtained, without permitting any of the steam or aroma of the flowers to escape. The boilers or digesters should, of course, have sufficient strength to resist any pressure to which they are exposed, and be furnished with the necessary appendages for ascertaining the pressure, and for introducing and withdrawing the materials when required.

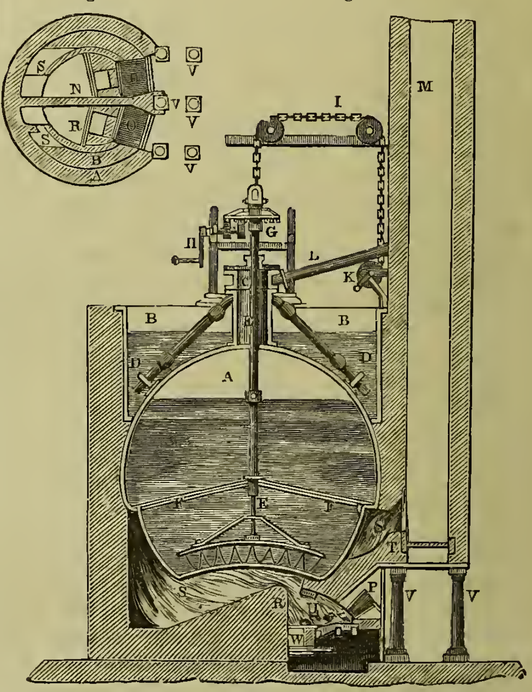
Such an arrangement is submitted as one of the many things which are deserving of trial by the enterprising brewer, and the Editor doubts not but that it would be productive of many advantages.

As yet, however, the brewers adhere to the boiling system; and as great revolutions in art and science cannot be expected to take place instantaneously, it may not be out of place to examine and discuss the system as generally carried out.

Before describing the several methods, the principal object in the boiling department will first be explained.

Figs. 161 and 162 represent the copper usually erected in breweries; the former being an elevated section, and the latter a ground plan, of the fire and flue. In fig. 161, A is the boiler or copper, hermetically sealed at the top, and convex at the bottom. Upon the top of this boiler is mounted a pan, B, in which water is heated by the caloric communicated to it during the boiling of the wort. A wide tube, C, rises from the uppermost part of the boiler, by which the steam, generated during the ebullition of the liquor, ascends, and is forced out by four tubes, two of which are seen at D D, into the liquor in the pan, B; the excess of vapor being carried off by the pipe, L, into the chimney. M. An iron shaft, E, passes down through a stuffing-box in the pipe, C, to the bottom of the vessel; at the lower end it is furnished with cross arms, from which chains are suspended, so as to sweep round the vessel. This mechanism is called *the rouser*, and its object is to prevent the matter which separates during the boiling from adhering to the metal and getting charred. It is worked by a cogged wheel on the axis of the winch, H, gearing into the wheel, G; and in order to remove the weight of the shaft off the wheel, it is partly supported at the bottom by a collar of metal borne by three stays, F F. It may be lifted by a chain, I, attached to its upper end, and, passing over the pulleys, is wound round the roller, K.

Fig. 162. Fig. 161.



This vessel, when unusually large, is heated by two fires, separated by a wall, N—Fig. 162; O O are the grates whereon the fire rests, and these are supplied, not through folding doors as formerly, but by short slanting iron hoppers—seen in Fig. 161—which are kept constantly full of coals. Above these hoppers a narrow aperture is formed for the admission of air, in such proportion as is sufficient to cause the complete combustion of the smoke. A bridge, R, at the back of each fire directs the flame upwards, so as to act upon the bottom of the copper, after which the heated vapors are conducted in semicircular flues, S S, round its sides, and finally it enters the chimney, M, on the lower part of which a sliding damper plate, T, is placed for tempering the draught. When cold air is admitted at this orifice, the combustion of the fuel is immediately checked. Besides this, there is another slide plate at the entrance of the slanting flue into the chimney, for regulating the play of the flame under and round the boiler. If the plate, T, be opened, and the other one shut, the power of the fire is suspended. There is an arch of brickwork, U, over the fire, to protect the front edge of the copper from the direct action of the flame. V V are the pillars on which the chimney is supported, and W is the opening through which the cinders and ashes are drawn away.

Sometimes, instead of the steam having free access through the pipes, D D, there is a weighted metallic valve, opening outward, and so contrived, that when the substance in the interior reaches 212°, no steam is permitted to escape, and therefore it accumulates till its pressure becomes too powerful to be restrained by the weight of the valve. It then escapes, and the few degrees of extra heat which had combined with the liquid during the formation of this pressure-steam, is carried off in that which passes away, and the heat of the remainder immediately falls to 212°, when the valve closes the orifice tightly, till there is a further quantity formed which forces it open as before. In this manner the boiling is continued during the allotted time; but, instead of permitting the escape of the steam, it is conducted into water, as in the preceding figure, as well for heating the liquor as for retaining any part of the aroma which is carried away by the vapor; this water is employed in subsequent mashings.

The criterion by which practical brewers judge of the completion of the work, is the *breaking*, or the formation of numerous flocks of coagulated matter; still, with the intent of increasing the preservative principle of the hop, the boiling is continued considerably after the above characteristic makes its appearance.

The following will give an idea of the courses pursued by various persons and on different occasions:—

1st, Ordinary ales, when the grist is exhausted in two or three mashings, are boiled thus—

First wort, ...	1 hour.
Second do., ...	2 hours.

2d, When there are three worts, the boiling is for the

First wort, ...	1 hour.
Second do., ...	1½ hour.
Third do., ...	2 hours.

In these cases, the first extract is boiled forty minutes before the hops are added, and fifteen minutes after; the gyle is then racked off, and the second worts are pumped into the copper, and treated as specified above. When the ale is to be stored, the practice is to add the hops and continue the ebullition till the coagulated matter agglutinates and falls to the bottom, after which the whole contents of the boiler are discharged to the store cask, which, when full, is tightly bunged, and then permitted to remain till the fermentation and depuration are spontaneously finished. Considerable time is required in this instance, often extending to twelve, eighteen, and even twenty-four months. Instead of putting the hops into the boiler with the wort, some persons pick or rub them between the hands, and when they are completely loosened, strew them on the bottom of the store cask, and run in the hot wort upon them after three-quarters of an hour's boil; when the cask is full it is bunged, as in the foregoing instance, and, if considered necessary, a safety-valve is appended. The fermentation and cleansing take place as in the preceding case. Where the object is to procure a highly-flavored aromatic ale, this practice is no doubt successful, especially when the hops are used in larger quantities than in ordinary cases; but in a commercial establishment the plan is now never adopted, though at one time it was much followed. Another custom is to macerate about a fourth of the hops with the worts, and boil, the remainder being reserved in the tun to be digested with the goods during the time allotted for the slow progressive fermentation, *et cetera.*

The trading brewers, in numerous cases, vary their operations, apparently with little advantage; but the following seems to be the usual routine:—Whilst the wort is being pumped into the copper, the hops are weighed out, according to the allowance per quarter, picked, and thrown on the surface of the liquor, when the boiling is performed in the open pan; but macerated with it when the closed copper is used. The layer of hops excludes contact with the air to some extent till the wort rises to ebullition, and thus any injury which might arise by spontaneous decomposition, till the temperature of the liquor reaches to 212°, is avoided. For some time the steam is allowed to permeate the hops to open their pores, for the abstraction of their bitter and other constituents, before they are beaten into the wort, and the boiling continued till the formation of the flocks, or for a specified time, say one, two, or, in case of stock ales which are exported, for three hours. In addition to the albumen which would separate from the worts by mere boiling, the tannin of the hop unites with a further quantity and precipitates it, leaving the menstruum comparatively purer, and impregnated with the preservative bitter of the flower.

The quantity of hops added to the wort is dependent upon the quality of the product and the strength of the worts, and also upon the length of time they are to be retained, or the climate they have to endure. The quality of the flowers has also an influence upon the proportion required to communicate the requisite properties to the liquor. For this reason the ales prepared for the export trade, such as East India pale ales, *et cetera*, are always more richly hopped than those used for home consumption, though of late years the preceding class has been consumed at home in considerable quantities, owing to its superiority. The allowance of hops per quarter of malt will be found in the annexed table from LEVESQUE; it extends from one-eighth of a pound to fourteen pounds per quarter. Some of the finest ales made to keep good in hot climates, have a larger quantity of hops added to them than is here mentioned, amounting sometimes to eighteen or twenty-two pounds per quarter of malt, whereas the proportion allotted to the common variety is not more than from six to eight pounds, and very rarely ten pounds. It is very common to add only four pounds of hops per quarter to the wort, especially when it is of an inferior kind; as, however, the brewer is to be guided by his own taste in the production of a bitter or a mild article, the quantities laid down in the table are the only convenient advantage which can be here afforded him:—

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 pounds per quarter.

Gravity.	⅛	¼	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾
70	0·1250	0·2500	0·5000	0·7500	1·0000	1·2500	1·5000	1·7500	2·0000	2·2500	2·5000	2·7500
71	0·1267	0·2535	0·5070	0·7607	1·0142	1·2678	1·5214	1·7750	2·0285	2·2821	2·5864	2·7892
72	0·1284	0·2570	0·5140	0·7714	1·0284	1·2856	1·5428	1·8000	2·0570	2·3142	2·6228	2·8284
73	0·1301	0·2605	0·5210	0·7821	1·0426	1·3034	1·5642	1·8250	2·0855	2·3463	2·6592	2·8676
74	0·1318	0·2640	0·5280	0·7928	1·0568	1·3212	1·5856	1·8500	2·1140	2·3784	2·6956	2·9068
75	0·1335	0·2675	0·5350	0·8035	1·0710	1·3390	1·6070	1·8750	2·1425	2·4105	2·7320	2·9460
76	0·1352	0·2710	0·5420	0·8142	1·0852	1·3568	1·6284	1·9000	2·1710	2·4426	2·7684	2·9852
77	0·1369	0·2745	0·5490	0·8249	1·0994	1·3746	1·6498	1·9250	2·1995	2·4747	2·8048	3·0244
78	0·1386	0·2780	0·5560	0·8356	1·1136	1·3924	1·6712	1·9500	2·2280	2·5068	2·8412	3·0636
79	0·1403	0·2815	0·5630	0·8463	1·1278	1·4102	1·6920	1·9750	2·2565	2·5389	2·8776	3·1028
80	0·1420	0·2850	0·5700	0·8570	1·1420	1·4280	1·7140	2·0000	2·2850	2·5710	2·9140	3·1420
81	0·1437	0·2885	0·5770	0·8677	1·1562	1·4458	1·7354	2·0250	2·3135	2·6031	2·9504	3·1812
82	0·1454	0·2920	0·5840	0·8784	1·1704	1·4636	1·7568	2·0500	2·3420	2 6352	2·9868	3·2204
83	0·1471	0·2955	0·5910	0·8891	1·1846	1·4814	1·7782	2·0750	2·3705	2·6673	3·0232	3 2596
84	0·1488	0·2990	0·5980	0·8998	1·1988	1·5092	1·7996	2·1000	2·3990	2·6994	3·0596	3·2988
85	0·1505	0·3025	0·6050	0·9105	1·2130	1·5260	1·8210	2·1250	2·4275	2·7315	3·0960	3·3380
86	0·1522	0·3060	0·6120	0·9212	1·2272	1·5438	1·8424	2·1500	2·4560	2·7636	3·1324	3·3772
87	0·1539	0·3095	0·6190	0·9319	1·2414	1·5616	1·8638	2·1750	2·4845	2·7957	3·1688	3·4164
88	0·1556	0·3130	0·6260	0·9426	1·2556	1·5794	1·8852	2·2000	2·5130	2·8278	3·2052	3·4556
89	0·1573	0·3165	0·6330	0·9533	1·2698	1·5972	1·9066	2·2250	2·5415	2·8599	3·2416	3·4948
90	0·1590	0·3200	0·6400	0·9640	1·2840	1·6050	1·9280	2·2500	2·5700	2·8920	3·2780	3·5340
91	0·1607	0·3235	0·6470	0·9747	1·2982	1·6228	1·9494	2·2750	2·5985	2·9240	3·3144	3·5732
92	0·1624	0.3270	0·6540	0·9854	1·3124	1·6406	1·9708	2·3000	2·6270	2·9562	3·3508	3·6124
93	0·1641	0·3305	0·6610	0·9961	1·3266	1·6584	1·9922	2·3250	2·6555	2·9883	3·3872	3·6156
94	0·1658	0·3340	0·6680	1·0068	1·3408	1·6762	2·0136	2·3500	2·6840	3·0204	3·4236	3·6908
95	0·1675	0·3375	0·6750	1·0175	1·3550	1·6940	2·0350	2·3750	2·7125	3·0525	3·4600	3·7300
96	0·1692	0·3410	0·6820	1·0282	1·3692	1·7118	2·0564	2·4000	2·7410	3·0846	3·4964	3·7692
97	0·1709	0·3445	0·6890	1·0389	1·3834	1·7296	2·0778	2·4250	2·7695	3·1167	3·5328	3·8084
98	0·1726	0·3480	0·6960	1·0496	1·3976	1·7474	2·0992	2·4500	2·7980	3·1488	3·5692	3·8476
99	0·1743	0·3515	0·7030	1·0603	1·4118	1·7652	2·1206	2·4750	2·8265	3·1809	3·6056	3·8868
100	0·1760	0·3550	0·7100	1·0710	1·4260	1·7830	2·1423	2·5000	2·8550	3·2130	3·6420	3·9260
101	0·1777	0·3580	0·7170	1·0817	1·4402	1·8008	2·1634	2·5250	2·8835	3·2451	3·6784	3·9652
102	0·1794	0·3620	0·7240	1·0924	1·4544	1·8186	2·1848	2·5500	2·9120	3·2772	3·7148	4·0044
103	0·1811	0·3655	0·7310	1·1031	1·4686	1·8364	2·2062	2·5750	2·9405	3·3093	3·7512	4·0436
104	0·1828	0·3698	0·7380	1·1008	1·4828	1·8542	2·2276	2·6000	2·9690	3·3414	3·7876	4·0828
105	0·1845	0·3725	0·7450	1·1245	1·4970	1·8720	2·2490	2·6250	2·9975	3·3735	3·8240	4·1220

TABLE continued.

Gravity.	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾
70	3·0000	3·2500	3·5000	3·7500	4·0000	4·2500	4·5000	4·7500	5·0000	5·2500	5·5000	5·7500
71	3·0428	3·2964	3·5500	3·8035	4·0571	4·3107	4·5642	4·8178	5·0714	5 3250	5·5785	5·8321
72	3·0856	3·3428	3·6000	3·8570	4·1142	4·3714	4·6284	4·8856	5·1428	5·4000	5·6570	5·9142
73	3·1284	3·3892	3·6500	3·9705	4·1713	4·4321	4·6926	4·9534	5·2142	5·4750	5·7355	5·9963
74	3 1712	3·4356	3·7000	3·9640	4·2284	4·4928	4·7568	5·0212	5·2856	5·5500	5·8140	6·0784
75	3·2140	3·4820	3·7500	4·0175	4·2855	4·5535	4·8210	5·0890	5·3570	5·6250	5·8925	6·1605
76	3·2568	3·5284	3·8000	4·0710	4·3426	4·6142	4·8852	5·1568	5·4284	5·7000	5·9710	6·2426
77	3·2996	3·5748	3·8500	4·1245	4·3994	4·6749	4·9494	5·2246	5·4998	5·7750	6·0495	6·3247
78	3·3424	3·6212	3·9000	4·1780	4·4568	4·7356	5·0136	5·2924	5·5712	5·8500	6·1280	6·4068
79	3·3852	3·6676	3·9500	4·2315	4·5139	4·7963	5·0778	5·3602	5·6426	5·9250	6·2065	6·4889
80	3·4280	3·7140	4·0000	4·2850	4·5710	4·8570	5·1420	5·4280	5·7140	6·0000	6·2850	6·5710
81	3·4708	3·7604	4·0500	4·3385	4·6281	4·9177	5·2062	5·4958	5·7854	6·0750	6·3635	6·6531
82	3·5136	3·8068	4·1000	4·3920	4·6852	4·9784	5·2704	5·5636	5·8568	6·1500	6·4420	6·7352
83	3·5564	3·8532	4·1500	4·4455	4·7423	5·0391	5·3346	5·6314	5·9282	6·2250	6·5205	6·8173
84	3·5992	3·8996	4·2000	4·4990	4·7994	5·0998	5·3998	5·6992	5·9996	6·3000	6·5990	6·8994
85	3·6420	3·9460	4·2500	4·5525	4·8565	5·1605	5·4630	5·7670	6·0710	6·3750	6·6775	6·9815
86	3·6848	3·9924	4·3000	4·6060	4·9136	5·2212	5·5272	5·8348	6·1424	6·4500	6·7560	7·0636
87	3·7276	4·0388	4·3500	4·6595	4·9707	5·2819	5·5914	5·9026	6·2138	6·5250	6·8345	7·1457
88	3·7704	4·0852	4·4000	4·7130	5·0278	5·3426	5·6556	5·9704	6·2852	6·6000	6·9130	7·2278
89	3·8132	4·1316	4·4500	4·7665	5·0849	5·4033	5·7198	6·0382	6·3566	6·6750	6·9915	7·3099
90	3·8560	4·1780	4·5000	4·8200	5·1420	5·4640	5·7840	6·1060	6·4280	6·7500	7·0700	7·3920
91	3·8988	4·2244	4·5500	4·8735	5·1991	5·5247	5·8482	6·1738	6·4994	6·8250	7·1485	7·4741
92	3·9416	4·2708	4·6000	4·9270	5·2562	5·5854	5·9124	6·2416	6·5708	6·9000	7·2270	7·5562
93	3·9844	4·3172	4·6500	4·9805	5·3133	5·6461	5·9766	6·3094	6·6422	6·9750	7·3055	7·6383
94	4·0272	4·3636	4·7000	5·0340	5·3704	5·7068	6·0408	6·3772	6·7136	7·0500	7·3840	7·7204
95	4·0700	4·4100	4·7500	5·0875	5·4275	5·7675	6·1050	6·4450	6·7850	7·1250	7·4625	7·8025
96	4·1128	4·4564	4·8000	5·1410	5·4846	5·8282	6·1692	6·5128	6·8564	7·2000	7·5410	7·8846
97	4·1556	4·5028	4·8500	5·1945	5·5417	5·8889	6·2334	6·5806	6·9278	7·2750	7·6195	7·9667
98	4·1984	4·5492	4·9000	5·2480	5·5988	5·9496	6·2976	6·6484	6·9992	7·3500	7·6980	8·0488
99	4·2412	4·5956	4·9500	5·3015	5·6559	6·0103	6·3618	6·7162	7·0706	7·4250	7·7765	8·1309
100	4·2840	4·6420	5·0000	5·3550	5·7130	6·0710	6·4260	6·7840	7·1420	7·5000	7·8550	8·2130
101	4·3268	4·6884	5·0500	5·4085	5·7701	6·1317	6·4902	6·8518	7·2134	7·5750	7·9335	8·2951
102	4·3696	4·7348	5·1000	5·4620	5·8272	6·1924	6·5544	6·9196	7·2848	7·6500	8·0120	8·3772
103	4·4124	4·7812	5·1500	5·5155	5·8843	6·2531	6·6186	6·9874	7·3562	7·7250	8·0905	8·4593
104	4·4552	4·8276	5·2000	5·5690	5·9414	6·3138	6·6828	7·0552	7·4276	7·8000	8·1690	8·5414
105	4·4980	4·8740	5·2500	5·6225	5·9985	6·3745	6·7470	7·1230	7·4990	7·8750	8·2475	8·6235

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 pounds per quarter.—Continued.

Gravity.	6	6¼	6½	6¾	7	7¼	7½	7¾	8	8¼	8½
70	6·0000	6·2500	6·5000	6·7500	7·0000	7·2500	7·5000	7·7500	8·0000	8·2500	8·5000
71	6·0857	6·3392	6·5928	6·8464	7·1000	7·3535	7·6071	7·8607	8·1142	8·3678	8·6214
72	6·1714	6·4284	6·6856	6·9428	7·2000	7·4570	7·7142	7·9714	8·2284	8·4856	8·7428
73	6·2571	6·5176	6·7784	7·0392	7·3000	7·5605	7·8213	8·0821	8·3426	8·6034	8·8642
74	6·3428	6·6068	6·8712	7·1356	7·4000	7·6640	7·9284	8·1928	8·4568	8·7212	8·9850
75	6·4285	6·6960	6·9640	7·2320	7·5000	7·7675	8·0355	8·3035	8·5710	8·8390	9·1070
76	6·5142	6·7852	7·0568	7·3284	7·6000	7·8710	8·1426	8·4142	8·6852	8·9568	9·2284
77	6·5999	6·8744	7·1496	7·4240	7·7000	7·9745	8·2497	8·5249	8·7994	9·0746	9·3498
78	6·6856	6·9636	7·2424	7·5212	7·8000	8·0780	8·3568	8·6356	8·9136	9·1924	9·4712
79	6·7713	7·0528	7·3352	7·6176	7·9000	8·1815	8·4639	8·7463	9·0278	9·3102	9·5927
80	6·8570	7·1420	7·4280	7·7140	8·0000	8·2850	8·5710	8·8570	9·1420	9·4280	9·7140
81	6·9427	7·2312	7·5208	7·8104	8·1000	8·3885	8·6781	8·9677	9·2562	9·5458	9·8354
82	7·0284	7·3204	7·6136	7·9068	8·2000	8·4920	8·7852	9·0784	9·3704	9·6636	9·9568
83	7·1141	7·4096	7·7064	8·0032	8·3000	8·5955	8·8923	9·1891	9·4846	9·7814	10·0782
84	7·1998	7·4988	7·7992	8·0996	8·4000	8·6996	8·9994	9·2998	9·5998	9·8992	10·1996
85	7·2855	7·5880	7·8920	8·1960	8·5000	8·8025	9·1065	9·4105	9·7130	10·0170	10·3210
86	7·3712	7·6772	7·9848	8·2924	8·6000	8·9060	9·2136	9·5212	9·8272	10·1348	10·4424
87	7·4569	7·7664	8·0776	8·3888	8·7000	9·0005	9·3207	9.6319	9·9414	10·2526	10·5638
88	7·5426	7·8556	8·1704	8·4852	8·8000	9·1130	9·4278	9·7426	10·0516	10·3704	10·6852
89	7·6283	7·9448	8·2632	8·5816	8·9000	9·2165	9·5349	9·8533	10·1698	10·4882	10·8006
90	7·7140	8·0340	8·3560	8·6780	9·0000	9·3200	9·6420	9·9640	10·2840	10·6060	10·9280
91	7·7997	8·1232	8·4488	8·7744	9·1000	9·4235	9·7491	10·0747	10·3982	10·7238	11·0494
92	7·8854	8·2124	8·5416	8·8708	9·2000	9·5270	9·8562	10·1854	10·5124	10·8416	11·1708
93	7·9771	8·3016	8·6344	8·9672	9·3000	9·6305	9·9633	10·2961	10·6266	10·9514	11·2922
94	8·0568	8·3908	8·7272	9·0636	9·4000	9·7340	10·0704	10·4068	10·7408	11·0772	11·4136
95	8·1425	8·4800	8·8200	9·1600	9·5000	9·8375	10·1775	10·5175	10·8550	11·2950	11·5350
96	8·2282	8·5692	8·9128	9·2564	9·6000	9·9410	10·2846	10·6282	10·9692	11·3128	11·6564
97	8·3139	8·6584	9·0056	9·3528	9·7000	10·0445	10·3917	10·7389	11·0834	11·4306	11·7778
98	8·3996	8·7476	9·0984	9·4492	9·8000	10·1480	10·4988	10·8496	11·1976	11·5484	11·8992
99	8·4853	8·8368	9·1912	9·5456	9·9000	10·2515	10·6059	10·9603	11·3118	11·6662	12·0206
100	8·5710	8·9260	9·2840	9·6420	10·0000	10·3550	10·7130	11·0710	11·4260	11·7840	12·1420
101	8·6567	9·0152	9·3768	9·7384	10·1000	10·4585	10·8201	11·1817	11·5402	11·9018	12·2634
102	8·7424	9·1044	9·4696	9·8348	10·2000	10·5620	10·9272	11·2924	11·6544	12·0196	12·3848
103	8·8281	9·1936	9·5624	9·9312	10·3000	10·6655	11·0343	11·4031	11·7686	12·1374	12·5062
104	8·9138	9·2828	9·6552	10·0276	10·4000	10·7690	11·1414	11·5138	11·8828	12·2552	12·6267
105	8·9995	9·3720	9·7480	10·1240	10·5000	10·8725	11·2485	11·6245	11·9970	12·3730	12·7490

TABLE continued.

Gravity.	8¾	9	9¼	9½	9¾	10	10¼	10½	10¾	11	11¼
70	8·7500	9·0000	9·2500	9·5000	9·7500	10·0000	10·2500	10·5000	10·7500	11·0000	11·2500
71	8·8750	9·1285	9·3821	9·6357	9·8892	10·1428	10·3964	10·6500	10·9035	11·1571	11·4107
72	9·0000	9·2570	9·5142	9·7714	10·0284	10·2856	10·5428	10·8000	11·0570	11·3142	11·5714
73	9·1250	9·3855	9·6463	9·9071	10·1676	10·4284	10·6892	10·9500	11·2105	11·4713	11·7321
74	9·2500	9·1140	9·7784	10·0428	10·3068	10·5712	10·8356	11·1000	11·3640	11·6284	11·8928
75	9·3750	9·6465	9·9105	10·1785	10·4460	10·7140	10·9820	11·2500	11·5175	11·7855	12·0535
76	9·5000	9·7710	10·0426	10·3142	10·5852	10·8568	11·1284	11·4000	11·6710	11·9426	12·2142
77	9·6250	9·8995	10·1747	10·4499	10·7244	10·9996	11·2748	11·5500	11·8245	12·0997	12·3749
78	9·7500	10·0280	10·2068	10·5856	10·8636	11·1424	11·4212	11·7000	11·9780	12·2568	12·5356
79	9·8750	10·1565	10·4389	10·7213	11·0028	11·2852	11·5676	11·8500	12·1315	12·4139	12·6963
80	10·0000	10·2850	10·5710	10·8570	11·1420	11·4280	11·7140	12·0000	12·2850	12·5710	12·8570
81	10·1250	10·4135	10·7031	10·9927	11·2812	11·5708	11·8604	12·1500	12·4385	12·7281	13·0177
82	10·2500	10·5420	10·8352	11·1284	11·4204	11·7136	12·0068	12·3000	12·5920	12·8852	13·1784
83	10·3750	10·6705	10·9673	11·2641	11·5296	11·8564	12·1532	12·4500	12·7455	13·0423	13·3391
84	10·5000	10·7990	11·0994	11·3998	11·6988	11·9992	12·2996	12·6000	12·8990	13·1994	13·4998
85	10·6250	10·9275	11·2315	11·5355	11·8380	12·1420	12·4460	12·7500	13·0525	13·3565	13·6605
86	10·7500	11·0560	11·3636	11·6712	11·9772	12·2848	12·5924	12·9000	13·2660	13·5136	13·8212
87	10·8750	11·1845	11·4957	11·8069	12·1164	12·4276	12·7388	13·0500	13·3595	13·6707	13·9819
88	11·0000	11·3130	11·6278	11·9426	12·2556	12·5704	12·8852	13·2000	13·5130	13·8278	14·1426
89	11·1250	11·4415	11·7599	12·0783	12·3948	12·7132	13·0316	13·3500	13·6665	13·9849	14·3033
90	11·2500	11·5700	11·8920	12·2140	12·5340	12·8560	13·1780	13·5000	13·8200	14·1420	14·4640
91	11·3750	11·6985	12·0241	12·3497	12·6732	12·9988	13·3244	13·6500	13·9735	14·2991	14·6247
92	11·5000	11·8270	12·1562	12·4854	12·8124	13·1416	13·4708	13·8000	14·1270	14·4562	14·7854
93	11·6250	11·9555	12·2883	12·6211	12·9516	13·2844	13·6172	13·9500	14·2805	14·6133	14·9461
94	11·7500	12·0840	12·4204	12·7568	13·0908	13·4272	13·7636	14·1000	14·4340	14·7704	15·1068
95	11·8750	12·2125	12·5525	12·8925	13·2300	13·5700	13·9100	14·2500	14·5875	14·9275	15·2675
96	12·0000	12·4410	12·6846	13·0282	13·3692	13·7128	14·0564	14·4000	14·7410	15·0846	15·4282
97	12·1250	12·5695	12·8167	13·1639	13·5084	13·8556	14·2028	14·5500	14·8945	15·2417	15·5899
98	12·2500	12·6980	12·9488	13·2996	13·6476	13·9984	14·3492	14·7000	15·0480	15·3988	15·7496
99	12·3750	12·8265	13·0809	13·4353	13·7868	14·1412	14·4496	14·8500	15·2015	15·5559	15·9103
100	12·5000	12·9550	13·2130	13·5710	13·9260	14·2840	14·6420	15·0000	15·3550	15·7130	16·0710
101	12·6250	13·0835	13·3451	13·7067	14·0652	14·4268	14·7884	15·1500	15·5085	15·8701	16·2317
102	12·7500	13·2120	13·4772	13·8424	14·2044	14·5696	14·9348	15·3000	15·6620	16·0272	16·3924
103	12·8750	13·3405	13·5093	13·9781	14·3436	14·7124	15·0812	15·4500	15·8155	16·1843	16·5531
104	13·0000	13·4680	13·7414	14·1138	14·4828	14·8552	15·2276	15·6000	15·9690	16·3414	16·7138
105	13·1250	13·5965	13·8735	14·2495	14·6220	14·9980	15·3740	15·7500	16·1225	16·4985	16·8745

TABLE showing the quantity of hops per quarter of malt of any gravity from 70 to 105 pounds, at the ratio of ⅛ to 14 lbs. per quarter.—Concluded.

Gravity.	11½	11¾	12	12¼	12½	12¾	13	13¼	13½	13¾	14
70	11·5000	11·7500	12·0000	12·2500	12·5000	12·7500	13·0000	13·2500	13·5000	13·7500	14·0000
71	11·6642	11·9178	12·1714	12·4250	12·6785	12·9321	13·1857	13·4392	13·6928	13·9464	14·2000
72	11·8284	12·0856	12·3428	12·6000	12·8570	13·1142	13·3714	13·6284	13·8865	14·1428	14·4000
73	11·9926	12·2534	12·5412	12·7750	13·0320	13·2963	13·5571	13·8176	14·0784	14·3392	14·6000
74	12·1568	12·4212	12·6856	12·9500	13·2105	12·4784	13.7428	14·0068	14·2712	14·5356	14·8000
75	12·3210	12·5890	12·8570	13·1250	13·3890	13·6605	13·9285	14·1960	14·4640	14·7320	15·0000
76	12·4852	12·7568	13·0284	13·3000	13·5675	13·8426	14·1142	14·3852	14·6568	14·9284	15·2000
77	12·6494	12·9246	13·1998	13·4750	13·7460	14·0247	14·2999	14·5744	14·8496	15·1248	15·4000
78	12·8136	13·0924	13·3712	13·6500	13·9245	14·2068	14·4856	14·7636	15·0424	15·3212	15·6000
79	12·9778	13·2602	13·5426	13·8250	14·1030	14·3889	14·6713	14·9528	15·2352	15·5176	15·8000
80	13·1420	13·4280	13·7140	14·0000	14·2815	14·5710	14·8570	15 1410	15·4280	15·7140	16·0000
81	13·3062	13·5958	13·8885	14·1750	14·4600	14·7531	15·0427	15·3302	15·6208	15·9404	16·2000
82	13·4704	13·7636	14·0568	14·3500	14·6385	14·9352	15·2284	15·5194	15·8136	16·1068	16·4000
83	13·6346	13·9314	14·2282	14·5250	14·8170	15·1173	15·4141	15·7086	16·0064	16·3032	16·6000
84	13·7988	14·0992	14·3996	14·7000	14·9955	15·2994	15·5998	15·8978	16·1992	16·4996	16·8000
85	13·9630	14·2670	14·5710	14·8750	15·1740	15·4815	15·7855	16·0870	16·3920	16·6960	17·0000
86	14·1272	14·4348	14.7424	15·0500	15·3525	15·6636	15·9712	16·2762	16·5848	16·8924	17·2000
87	14·2914	14·6026	14·9138	15·2250	15·5310	15·8457	16·1569	16·4654	16·7776	17·0888	17·4000
88	14·4556	14·7740	15·0852	15·4000	15·7095	16·0278	16·3426	16·6546	16·9704	17·2852	17·6000
89	14·6198	14·9382	15·2566	15·5750	15·8880	16·2099	16·5283	16·8438	17·1632	17·4816	17·8000
90	14·7840	15·1060	15·4280	15·7500	16·0665	16·3920	16·7146	17·0320	17·3560	17·6780	18·0000
91	14·9482	15·2738	15·5994	15·9250	16·2450	16·5741	16·8997	17·2212	17·5488	17·8744	18·2000
92	15·1124	15·4416	15·7708	16·1000	16·4235	16·7562	17·0854	17·4104	17·7416	18·0708	18·4000
93	15·2766	15·6694	15·9422	16·2750	16·6020	16·9383	17·2711	17·6096	17·9344	18·2672	18·6000
94	15·4408	15·7772	16·1136	16·4500	16·7805	17·1204	17·4568	17·7988	18·1272	18·4636	18·8000
95	15·6050	15·9450	16·2850	16·6250	16·9590	17·3025	17·6425	17·9880	18·3200	18·6600	19·0000
96	15·7692	16·1128	16·4564	16·8000	17·1375	17·4846	17·8282	18·1772	18·5128	18·8564	19·2000
97	15·9334	16·2806	16·6278	16·9750	17·3160	17·6667	18·0139	18·3664	18·7056	19·0528	19·4000
98	16·0976	16·4484	16·7992	17·1500	17·4945	17·8488	18·1996	18·5556	18·8984	19·2492	19·6000
99	16·2618	16·6162	16·9706	17·3250	17·6730	18·0309	18·3853	18·7448	19·0912	19·4456	19·8000
100	16·4260	16·7840	17·1420	17·5000	17·8515	18·2130	18·5710	18·9340	19·2840	19·6420	20·0000
101	16·5902	16·9518	17·3134	17·6750	18·0300	18·3951	18·7567	19·1232	19·4768	19·8384	20·2000
102	16·7544	17·1196	17·4848	17·8500	18·2085	18·5772	18·9424	19·3124	19·6696	20·0348	20·4000
103	16·9186	17·2874	17·6562	18·0250	18·3870	18·7593	19·1281	19·5016	19·8624	20·2312	20·6000
104	17·0828	17·4552	17·8276	18·2500	18·5655	18·9414	19·3138	19·6908	20 0552	20·4276	20·8000
105	17·2470	17·6230	17·9990	18·3750	18·7440	19·1235	19·4995	19·8800	20·2480	20·6240	21·0000

If the produce of the malt be obtained in two or more mashings, and they are boiled separately, the proportion of hops which each wort will require is found as follows:—Suppose the quantity taken was eighty quarters of malt, and that the gravity per quarter is eighty-five pounds, the whole being extracted in two mashes, the first of which tests sixty-five pounds, and the other, together with the washings, twenty pounds per quarter; further, if the proportion of hops to the quarter of seventy pounds gravity be twelve pounds, by referring to the gravity, eighty-five pounds in the table, the number 14·571 will be found on the horizontal line under the head of twelve pounds per quarter. Then $85 \times 14{\cdot}571 = 1238{\cdot}5$ pounds of hops, and $80 \times 85 = 6800$ pounds, the total extract; and $6800 \div 1238{\cdot}5 = 0{\cdot}1821$ pounds of hops for each pound gravity in each of the worts; and hence $65 \times 80 \times 0{\cdot}182 = 946{\cdot}9$ pounds for the first wort, $20 \times 80 \times 0{\cdot}182 = 291{\cdot}6$ pounds for the second wort.

In a similar way, the proportion of the flowers which ought to be added to the several liquors is found, at whatever number of pounds per quarter, as specified in the table, is adopted.

Sometimes the whole of the hops is added to the first wort; but the time of boiling is shortened, so as to leave sufficient of the bitter principle for the next liquor; the practice most frequently followed is to add the proper quantity to each wort and discharge the whole, when the usual time of boiling is expired, into the hop-back. The ebullition in this case is continued for one half to three quarters of an hour longer in the second than in the first wort, to remove the excess of impurities which the after mashings generally carry along with them, and to exhaust the hops, as well as to concentrate the gyle, and procure a better quality of ale than they would afford in their diluted state. The brewer, however, applies here only an imperfect remedy for the self-inflicted malady of drawing off repeated mashings in a very diluted state, for by such a course of ebullition the sugar is partly decomposed as already explained, the menstruum deepens in color, and the expenditure in fuel becomes a dead loss; whereas, if the precautions alluded to in the foregoing pages be observed, most of these disadvantages will not be experienced. After the boiling, the gyle and hops are drawn off to the hop-back, and the liquor is made to percolate through the hops used in the foregoing operation. Any strong wort which might be retained in the exhausted hops is carried off in the second gyle, and what is retained of the second is washed off with hot water, and the washings preserved for a return wort; or in case light ales are to be made, added to the product in the cooler; or the residuary fibrous matter of the hops is removed to the press, and the liquor squeezed out in this way added to the second gyle.

A larger quantity of hops is always used in hot weather than when the air is cold or mild, so as to prevent the decomposition of the ale, which, without this counteracting agent, the elevated temperature would occasion.

The following table, transcribed from LEVESQUE, specifies the increase of hops required for every degree from 50° to 75° Fahr., and from four to nine pounds per quarter:—

Temperature of the air at the time of brewing.	Four pounds per quarter.	Five pounds per quarter.	Six pounds per quarter.	Seven pounds per quarter.	Eight pounds per quarter.	Nine pounds per quarter.
50°	4·00	5·00	6·00	7·00	8·00	9·00
51	4·08	5·10	6·12	7·14	8·16	9·18
52	4·16	5·20	6·24	7·28	8·32	9·36
53	4·24	5·30	6·36	7·42	8·48	9·54
54	4·32	5·40	6·48	7·56	8·64	9·72
55	4·40	5·50	6·60	7·70	8·80	9·90
56	4·48	5·60	6·72	7·84	8·96	10·08
57	4·56	5·70	6·84	7·98	9·12	10·26
58	4·64	5·80	6·96	8·12	9·28	10·44
59	4·72	5·90	7·08	8·26	9·44	10·52
60	4·80	6·00	7·20	8·40	9·60	10·70
61	4·88	6·10	7·32	8·54	9·76	10·88
62	4·96	6·20	7·44	8·68	9·92	11·06
63	5·04	6·30	7·56	8·82	10·08	11·24
64	5·12	6·40	7·68	8·96	10·24	11·42
65	5·20	6·50	7·80	9·10	10·40	11·60
66	5·28	6·60	7·92	9·24	10·56	11·88
67	5·36	6·70	8·04	9·38	10·72	12·06
68	5·44	6·80	8·16	9·52	10·88	12·24
69	5·52	6·90	8·28	9·66	11·04	12·42
70	5·60	7·00	8·40	9·80	11·20	12·60
71	5·68	7·10	8·52	9·94	11·36	12·78
72	5·76	7·20	8·64	10·08	11·52	12·96
73	5·84	7·30	8·76	10·22	11·68	13·14
74	5·92	7·40	8·88	10·36	11·84	13·32
75	6·00	7·50	9·00	10·50	12·00	13·50

Notwithstanding that this table has evidently been drawn up from theory and not experiment, yet to practical men it may serve to some extent as a guide to direct them in weather unfavorable for brewing. The best guarantee would be to avoid as much as possible extracting the nitrogenous portions of the malt, or, when extracted, to separate them completely in the fermentation.

During the boiling, considerable quantities of water are expelled in the form of vapor, and a great difference is consequently observed between the density of the wort after boiling, and the gravity which it indicated at the time of its introduction into the copper.

The annexed table, copied also from LEVESQUE, shows what gravity the original wort ought to possess to afford a gyle of a certain strength after one hour's boiling:—

Gravity required after one hour's boiling.	Gravity required in the raw wort.	Gravity required after one hour's boiling.	Gravity required in the raw wort.
8	6·60	27	21·60
9	7·20	28	22·40
10	8·00	29	23·20
11	8·80	30	24·00
12	9·60	31	24·80
13	10·40	32	25·60
14	11·20	33	26·40
15	12·00	34	27·20
16	12·80	35	28·00
17	13·60	36	28·80
18	14·40	37	29·60
19	15·20	38	30·40
20	16·00	39	31·20
21	16·80	40	32·00
22	17·60	41	32·80
23	18·40	42	33·60
24	19·20	43	34·40
25	20·00	44	35·20
26	20·80	45	36·00

According to RICHARDSON, the volume of wort imbibed by the hops is as follows:—

Hops used.	Wort imbibed.	Hops used.	Wort imbibed.
Pounds.	Bar.	Pounds.	Bar.
1	0·01	30	0·50
2	0·03	40	0·66
3	0·05	50	0·83
4	0·06	60	1·00
5	0·08	70	1·16
6	0·10	80	1·33
7	0·11	90	1·50
8	0·13	100	1·66
9	0·15	200	3·33
10	0·16	300	5·00
11	0·17	400	6·66
12	0·19	500	8·33
13	0·21	600	10·00
14	0·22	700	11·66
15	0·24	800	13·32
16	0·26	900	15·00
17	0·27	1000	16·66
18	0·29	2000	33·30
19	0·31	3000	50·00
20	0·33	4000	66·66

The back into which the hops and wort are discharged is usually a large square vessel of wood or iron, with a perforated false bottom and a tap appended, not unlike the construction of the mash tun. When the contents of the copper are to be drawn off, the *rouser*, or other agitating apparatus, is set in motion to raise the hops in the liquor; and when the whole is removed to the back, some time is allowed to elapse before the gyle is drawn off to the refrigerators, in order that the hops may subside, and retain any mechanical impurities which may be floating in the liquid as it filters through them. Many persons, especially in Scotland, instead of employing an apparatus like that mentioned, erect a large square, with a temporary bottom or strainer, made of hair, and into this the hops and gyle are discharged. In this case the liquor is not so transparent as in the former; but it seems to be a disputed point, whether the finer portions of the hop grains that are carried through with the coagulated albumen are serviceable as a preservative to the beer, which is maintained by the practisers of the Scotch method chiefly on the ground, that a larger quantity of albuminous and glutinous matter is deposited with the hop grains in the coolers, and that the gyle is therefore much better purified than by the practice of filtering through the hops, as in the first method.

COOLING.—After the worts are thoroughly hopped and boiled, the next thing to be done is to bring them to a proper temperature for the commencement of the fermentation, which, to insure success, must be conducted within certain limits. The liquor, in this case, must be rapidly cooled, for, if permitted to remain in contact with the air during the time its caloric would be given off spontaneously, the consequence would be, that, unless the atmosphere were very cold, acidity would set in. Two methods are resorted to for cooling the worts, both of which are to a great extent artificial. The first has been practised for a considerable period, and is, therefore, sanctioned by the great majority of brewers; but the latter, which is of recent introduction, is much more effectual, and is generally to be found in the factories of the better-informed class in the trade.

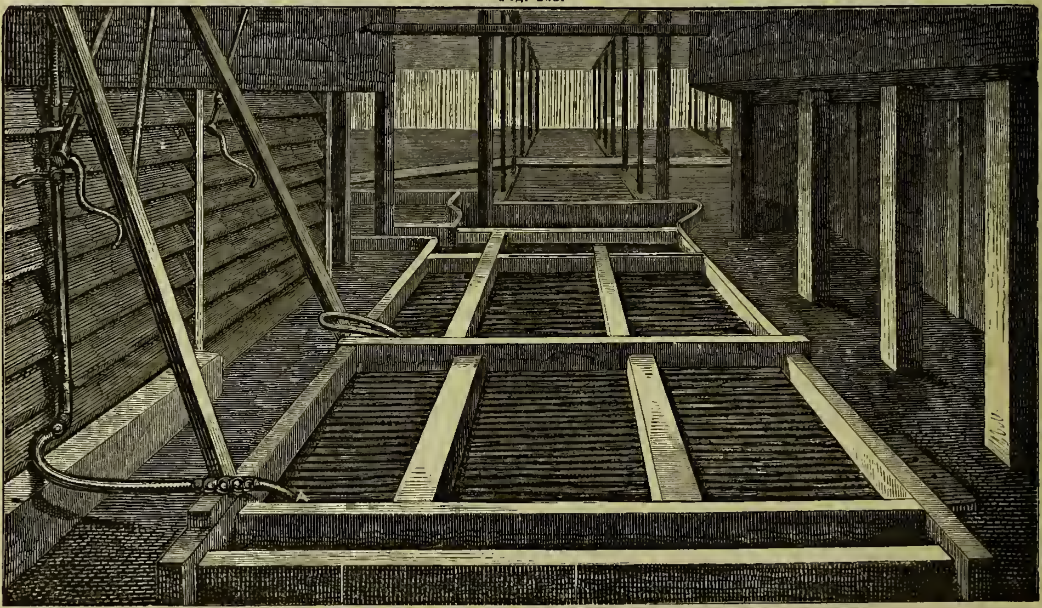
The apparatus used in the first instance is known as the *cooler*, and in the second as the *refrigerator*.

Coolers are spacious rectangular shallow vessels, for the most part constructed of Dantzic deal boards, two inches thick at the sides, and one inch and a quarter or one and a half at the bottom; these boards are connected by plain joints, to which they are secured by pins of the same wood. The depth of the cooler is about six inches, and it should be perfectly smooth, so that no impurities can be retained, which would be the case when the worts are drawn off, were any inequalities or rough knots in the floor; it should have a gentle incline towards that end at which the gyle is discharged into the fermenting-backs, and be placed in a position where the air has free access to it. For this reason the cooling floor is always in an elevated part of the brewery, and exposed on all sides by means of boards arranged in the same manner as a Venetian sun-blind. To expedite the work, fans or other mechanical agencies, similar to those noticed at page 64, are used, to increase the current of air in the apartment, whereby the heat is more readily dissipated than if allowed to radiate spontaneously. The gyle is streamed upon this floor to the depth of two or two and a half inches, and when the atmosphere is rather cold, as from the latter end of autumn to the middle of spring, the stratum cools in six to eight hours; but even this is too long for the liquor to remain exposed to the air.

Considerable loss, indeed, is often incurred by the imperfection of this method of cooling by the wooden floor, especially in warm weather, when the atmosphere is of a comparatively high temperature; for, in the first place, the liquor is not reduced in its heat so readily as to be entirely exempt from acidity; and, in the second, the wood of the vessel experiences considerable change in the alternate application of heat and cold, by which its pores are distended so much, that if allowed to remain exposed for any length of time, air enters, and this coming in contact with the gyle in the next operation, it operates on its saccharine and albuminous constituents, and occasions a creaming of the surface, or an incipient fermentation, technically known as the *fox*.

This evil may be partially prevented by keeping the floor covered with cold water, after the worts have been drawn off and the deposited matter cleaned away, till the next operation; but still the wood is liable to communicate acidity, unless the greatest attention be given to its being thoroughly washed very frequently with lime water. It is much more advisable to have the coolers constructed of some other material than wood, and, indeed, they are so formed by several brewers. Iron, when carefully attended to in point of cleansing, *et cetera*, answers very well, but tinned copper would be much more satisfactory. Sheet-iron, glazed or enamelled, would answer the purposes of the brewer admirably in this respect. TIZARD recommends to have the coolers formed of tiles made from felspar by a Manchester patentee, as being very eligible; and it cannot be doubted that, in point of cleanliness and security from foxing or acquiring a bad taste, such tiles would be preferable to wood, and might generally answer; but still they are not so good conductors of heat as iron or copper, and hence they would not cool the liquid so readily as these metals.

Fig. 163.



The refrigerators occupy no more than one-half or three-eighths of the space which the plain coolers take up; they are constructed, like the latter, in the form of a plane, with transverse divisions or bars issuing from each side alternately, and reaching to within half a foot of the opposite side; the space between each bar is usually about a foot or a foot and a half, and in this a pipe of suitable calibre is laid, through which cold water is made to flow in an opposite direction to the current of the gyle.

Fig. 163 represents the refrigerator in use at the factory of Messrs. ALLSOPP and SONS; the water pipe, entering at the lower end, is seen at A, and passes off at the further end, where the hot worts are being discharged into the cooler.

When the worts are cooled on the open floor, considerable quantities of deposit are formed, which in some instances are swept off into the fermenting-backs. The chief aim of the manager should be to cool the liquor as readily as possible, especially when the temperature reaches 130° Fahr.; the floor and pipes should also be kept scrupulously clean, otherwise the goods will either acquire a very bad taste or turn acid. When refrigerators are not erected, the best way would be to have the cooling floors so constructed that they could be exposed when required. If this were done, and the worts were streamed upon them during the night in summer, they would cool very rapidly in consequence of the heat being radiated into the clear atmosphere. After the gyle is cooled to the limits of 56° to 64°, it is transferred to the fermenting squares to undergo the next process, namely,

FERMENTATION.—In the whole course of brewing, there is no part of the work which requires such indefatigable diligence as the fermentation of the wort, as upon it depends the perfect accomplishment of the business; for if the foregoing stages had been performed somewhat imperfectly, provided the products have not acidified, and they have been subjected to a good fermentation, a wholesome beverage is obtained; but let the mashing and the other operations be ever so studiously executed, if the fermentation is imperfect, a bad and almost worthless product results. Yet, by care and moderate experience, it may be easily managed, so as to guard against the possibility of a failure.

The principles of the vinous fermentation have been alluded to at sufficient length at page 64 *et seq.*, to which the reader is referred; and knowing, from the explanation there given, what are its effects, and wherein it has to be counteracted, the chief aim should be the acquisition of the best practical knowledge for conducting it.

It is worth observing, however, that there are various species of chemical decompositions characterized by the term fermentation, such as the *lactic*, the *mucic*, the *ammoniacal*, the *acetous*, the *panary*, the *putrid*, the *vinous*, and various others, whereby certain compounds are generated, but *always* by a direct or an indirect species of oxidation. According to the nature of the substances operated upon, one or more of these may be excited by the contact of a body undergoing the like decomposition. For instance, a compound in the state of the acetous or lactic fermentation, on being brought in contact with a solution of sugar, occasions the direct formation of either acetic or lactic acid in the liquid.

This being the case, it is evident that the greatest and most scrupulous care should be observed in selecting the barm, or store, which is employed to induce the action in the first instance, lest it may have contracted any acidity or putrefaction, which would certainly prove detrimental to the beer, as affecting its flavor, wholesomeness, and keeping properties.

The apparatus required for the fermentation are either circular tuns or squares, constructed of sheet-iron or Dantzic deal, and of a capacity suited to the quantity of materials employed; they are generally furnished with an attemperator, or pipe, through which either hot or cold water, as the temperature of the contents may be too high or too low, is transmitted. The liquid is introduced into these fermenting vessels at a temperature varying from 54° to 64° Fahr., according to the practice of different brewers. In England, the pitching heat is usually between 60° and 64°, or even higher; while in Scotland the temperature does not reach higher than 58°, except in some few cases. When the pitching heat is high, and the yeast is of a good quality and in sufficient abundance, the fermentation becomes ungovernable, unless there be an attemperator to check the rising heat; besides, the whole of the glutinous constituents of the gyle is not removed in the yeast, and the liquor does not cleanse satisfactorily, in consequence of an after fermentation which sets in, and is practically known as the *fret.* On the other hand, if the action proceeds sluggishly, so that the yeast remains in contact with the liquor at a temperature of 66° to 70° for some time, then, in addition to its being ropy, the disagreeable taste of the yeast that has to some extent entered upon the putrefactive fermentation, will be retained, and the product is what is termed *yeast-bitten.*

To guard against both these serious evils, it is necessary to be scrupulously careful that the store yeast is in a good and healthy condition, and also that the temperature is properly regulated, as well in reference to the bulk and gravity of the gyle, as to the state of the atmosphere. The practice observed by some brewers of beating the head of the yeast into the gyle, however it may seem to favor the operation, is not so indispensable as they would suppose; for if the action be engrafted in the liquid at the first, it will proceed with sufficient power to complete the work without the assistance offered by the new yeast being beaten into it.

With these considerations, the brewer may discharge his worts into the fermenting vessels at from 58° to 64°, according to the circumstances already alluded to; but, before he proceeds, it should be his duty to ascertain the mean temperature of the air in the room, to have the real density of his gyle, and the quantity in barrels and firkins noted in his book, so that he may be better able to judge of the rise of temperature, the degree of attenuation, and the waste suffered during the action, but, above all, the proportion of yeast or *store* to be added at the commencement. Various circumstances tend to influence the quantity of yeast which ought to be added to the gyle; hence, to give a definite rule in this particular is out of the question. By studious attention and moderate experience the brewer will be able to master the difficulty, especially when it is borne in mind that the variation takes place, firstly, and principally, with the quality of the store; secondly, with the degree of heat at which the malt had been dried, and the quality of the liquor used in mashing; thirdly, with the gravity of the worts; and fourthly, with the temperature of the liquor, and likewise that of the air at the time of pitching the tun.

Yeast is very variable in its effects, according to the time of its production, its succeeding management, its age and condition; for the purposes of fermentation it cannot be too fresh, to operate with energy. The best variety at present in use is collected from pale gyles, near the close of the alcoholic fermentation, and after the first or second skimming. The first portions of yeast thrown off are not solid enough, and they generally carry with them some of the liquid as well as glutinous matter not wholly transformed into yeast, which continues to undergo oxidation till the acetous or putrefactive change sets in; and it is needless to add that such yeast would be highly injurious, and ought to be avoided.

When collected as above described, it is sufficiently dense without any glutinous matter which has not undergone oxidation by the decomposition of the sugar and water of the gyle; and it is, besides, entirely protected during the period of its formation from contact with the air, and wholly free from the old store or ferment added to the liquor in the beginning. By using the yeast thus carefully provided, a much less quantity of it will be effectual than of the other kinds which may be taken at random.

If highly dried or patent malt has been taken, the yeast must be added in larger proportion than if the worts were extracted from pale malt, for the constituents of the grain undergo decomposition, in consequence of which the proportion of gluten is considerably reduced in the extract; and to make up this deficiency of matter by which new ferment is formed, and the action of the original ferment invigorated, a larger proportion of yeast must be supplied in the first instance. The same precaution must be observed when the temperature of the gyle is low, and a large amount of extract is present; for it is well known that only a definite quantity of sugar is converted into alcohol by the yeast which is added; and as soon as this transformation is effected, the ferment loses its vitality, and is incapable of furthering the action beyond this limit, so that, if there be not as much matter as will generate a natural ferment in the gyle, the excess of saccharum over the quantity which the yeast added will act upon remains intact. The temperature of the liquor and air at the period of fermenting, will greatly influence the rapidity of the fermentation; for when the degree of heat is elevated, the matter of the gyle will more readily commingle.

When the gravity of the gyle is about 45 pounds per barrel, and the temperature of setting 58° or 60° Fahr., the atmosphere being at the ordinary temperature and barometric pressure, provided the yeast be of that quality already spoken of, about two to two and a half pounds per barrel will be sufficient, and it may happen that this quantity will in some cases overstore the tun. In winter, on the contrary, the store per barrel is increased to three, and sometimes three and a half pounds; but then the heat of pitching is lower than in the preceding case.

When worts of 20, 25, 30, or 40 pounds per barrel —the usual strength of the ordinary ales—are fermented, a less weight of store must be added in proportion as their density decreases.

The intervals of adding the yeast, like the various other operations in brewing, are different with most brewers, some preferring to add the total quantity at once, while others reserve a portion to be subsequently introduced, in order to strengthen the fermentation. As in either case the results are satisfactory, the brewer must be left to his own discretion in this matter, being mindful, however, of the facts which may be gleaned from the preceding pages on the subject, and that it is necessary to have a healthy action inoculated in the gyle from the beginning, otherwise the fermentation will not be successful.

After the mixture of the yeast and gyle has been made some time, the action is observed by the rise of some minute bubbles of gas to the surface, which form on the sides of the vessels; as the operation advances, this ring of minute vesicles, or froth, as it is termed, becomes detached, and moves towards the centre, its place being in a short time occupied by another ring, which imitates its predecessor, and thus the rings succeed one another till the whole surface is covered.

The decomposition of the sugar being more perfectly engrafted in the menstruum, the liberation of carbonic acid is freer and more voluminous, and a hissing sound or effervescence is observed. The sugar being more and more rapidly decomposed, the froth swells to a larger extent, by retaining the carbonic acid in the viscid matter which rises to the top; but when the volume accumulated is so great that the tension of the yet imperfect yeast cannot restrain it, it bursts and causes inequalities in the head, which gives it the appearance of what the brewer terms *rocks*.

The froth, which hitherto was colorless, begins to be tinged yellow, and as the work proceeds, it turns either to a lightish or brownish yellow; but it is a better sign of the fermentation, if it remains of the former shade. At this period the head falls considerably, in consequence of the carbonic acid gas which accumulated during the preceding part of the operation, overcoming the elasticity of the yeast and escaping; the newly-formed yeast becomes more dense and viscid, and the fermentation is much diminished. Were the head permitted to remain in contact with the liquor after this period, it would very soon precipitate, and probably, by having entered upon a putrefactive decomposition, would give rise to the same in the liquor; at any rate, the disagreeable bitterness which characterizes stale or putrefying ferment would be discernible in the beer, and in this state, as already remarked, it is said to be yeast-bitten. To prevent such effect, the ferment is skimmed off, and by this means the cause is removed; the fermentation is also checked so as to prevent it from passing the desired limits; many, however, take off only the top surface, beat the remainder into the liquor, and continue the fermentation with renewed vigor, till all the albuminous matters are separated in the form of yeast, and the greatest part of the saccharum has been reduced to alcohol and carbonic acid. Such is the treatment usually applied to exported ales, or bitter beers, that are reserved for store.

In brewing mild ales it is necessary to have a certain quantity of the sugar unattenuated, so as to give more or less sweetness to the beverage, and therefore the barm is skimmed off, as above stated, to check the fermentation, and attain the end proposed.

It has been shown on several occasions, that when the vinous fermentation takes place in a liquor, it is always succeeded, provided the liquor be left to itself, by the acetous; it is the same in this instance, for if the fermented liquor were allowed to repose after the first action has ceased, and the product clarifies, it would in a very short time become turbid, absorb oxygen, eviscerate a mucilaginous matter—*mother of vinegar*—and turn sour. Such destruction is prevented by the cleansing process; but, before describing this operation, it will be necessary to allude to the patented and other improvements which have been lately introduced into the brewing business. In doing this, the practice so long and efficiently followed in Bavaria deserves to arrest the attention.

The great and distinguishing feature of the beers of that kingdom, which are slowly fermented, is that they do not contract any acescency when exposed to the air, whilst the products of English, Scotch, and French brewings will invariably become sour under such circumstances. In addition to this very characteristic mark of the soundness of Bavarian beers, they possess the other qualities by which good beer is always known, and hence the high estimation in which they are held by all parties. These valuable qualities are obtained by the perfect system of fermentation to which the worts are subjected, a system which in itself has solved one of the most beautiful theories connected with it. Allusion has been already made to the causes of acidity in the gyle when speaking of boiling, but the explanation of the Bavarian method of fermentation will afford a clearer illustration of the matter than that adverted to. In gyles, generally speaking, the proportion of gluten, with reference to its utility in producing yeast or assisting in the fermentation, is greater than that of the sugar to its requirements in the formation of spirit and giving *fulness* to the drink; and although much of this excess may be removed by the boiling, still, after the usual process of attenuation has been effected by the generality of brewers in this country, a very considerable quantity of glutinous substance remains dissolved, and it is this that exposes the liquors to so much danger of spoiling, whereas, if it were removed, no apprehension of decomposition need be entertained. The process of fermentation, as carried out in Bavaria, is simply such as will entirely remove this excess of nitrogenous matter in the worts, and leave the beer consisting of no other constituents but water, alcohol, sugar, and the conserving principle of the hop.

The course adopted is the following:—After the worts are boiled and hopped, they are spread out upon large shallow pans, in an atmosphere of from 45° to 50° Fahr., under ground, and the fermentation is allowed to proceed spontaneously in contact with the air, the heat of the liquor being restricted within the above limits. In three to six weeks, as the case may be, the attenuation is completed; but during this period the evolution of carbonic acid, and the formation of a barmy head, as in the fermentation already described, are quite different from what is observed in this country. Carbonic acid is indeed evolved, but only in minute globules, such as pass off from a liquid saturated with it at a high pressure; and as to the formation of a head of yeast, the surface is scarcely covered with a scum, so completely is the ferment precipitated to the bottom of the liquor in the form of a viscous slime. The material difference of the precipitated yeast in the Bavarian course of fermentation, and that which rises to the surface in the rapid process is, that the first is the result of a slow oxidation of the gluten, termed decay, or eremacausis; while, in the second instance, it proceeds from a destruction of the equilibrium existing between the particles of the compounds present in the worts, independently of the action of the air, and to this change the term *putrefaction* has been applied. Yeast produced by decay, or the slow absorption of oxygen, does not excite the putrefactive, but the decaying fermentation in a wort; while, if yeast or any analogous body undergoing the putrefactive state of decomposition be added, and the action it induces be restricted under a temperature of 50° Fahr., then, although the newly-formed yeast will occasion the putrefactive change in a fresh wort, yet, when the same operation is repeated several times in succession, that process, by which only the precipitated yeast is formed, takes place, and the deposited matter has lost the power of inducing the ordinary fermentation even at a moderately elevated temperature. This matter is capable, however, of causing a very protracted internal action in the sugar, whereby it is split into carbonic acid and alcohol without affecting in the slightest degree the gluten which may be held in solution. The contact of the already decayed gluten is necessary to induce a corresponding action in that held in solution, as well as to transform the sugar into alcohol and carbonic acid, and, after this, exposure to atmospheric air is indispensable; for if the latter be excluded, the further change in the materials of the gyle is entirely arrested in regard to the precipitation of the nitrogenous products. Were these conditions accompanied with a high temperature, the aim of the brewer would be frustrated; for the alcohol, as well as the gluten, would then undergo an eremacausis or oxidation, and the resulting product would be vinegar; but at the very low degree at which the Bavarians conduct the process, the alcohol is incapable of oxidation; meanwhile the gluten readily enters into combination with it, and precipitates.

With reference to the question whether the gluten assimilates oxygen from the air, or whether it takes it from the sugar or water, or by a decomposition of its own particles unites with the oxygen—this is a subject upon which much has been said, and in some cases the explanations are still mysterious and unsatisfactory. It is well known that in the slow fermentation in question, if the air were excluded the action would cease; but that the decomposition of the saccharum into alcohol and carbonic acid does not require air, and hence it must be taken up by the gluten; yet, whether it is directly combined with the other elements of this body, or whether it abstracts hydrogen from it, is another question no less intricate than the former. A chemical analysis would not be decisive on this point for many reasons known to chemists, analogies of which are numerous in the range of organic bodies, such as colorless and blue indigo. DUMAS found that the colorless body differed only in one equivalent of hydrogen from the blue variety; but whether the latter is simply the former united to oxygen, or whether the colorless compound is a hydride of the blue substance, is a matter difficult to decide; and, in the same manner, it is a question whether the precipitated decayed gluten is a combination with oxygen, or that the latter has abstracted hydrogen and formed water, leaving the insoluble substance. In the course of rapid fermentation, the same oxidation of the gluten must take place as in the slow process, except that it is not so thoroughly completed as in the latter case; and since the fermentation in the former is carried on out of contact with the air, it follows that the oxygen necessary either to dehydrate or oxidize the gluten, must be derived from some compound in the liquor. That water is decomposed is almost impossible, for the oxygen in water is held more powerfully in combination than it could possibly be in the new arrangement of the oxidized gluten; besides, it is well known that when organic complex substances undergo decomposition, the elements of such always resolve themselves into more permanent and simpler bodies. There remains, therefore, only one substance which, by its decomposition, affords oxygen, and that is the sugar.

In close fermenting tuns, the amount of yeast or ferment thrown off is in proportion to the quantity of sweet principle that enters into another species of decomposition, besides that which generates alcohol and carbonic acid; and hence it follows, that the entire weight of sugar is not changed into spirit in close fermentations, whereas, on the Bavarian principle, the whole, even to the last grain, may be converted into alcohol and the other products of the vinous fermentation. From what has been said upon this subject and its principles, the reader will readily discern the difference between the Bavarian beers, and those made in England and Scotland from malt and hops; in the latter, some gluten always remains, which, by a slow internal species of putrefactive oxidation, and at the high temperatures that usually pervade the atmosphere in summer weather, occasions the further eremacausis or oxidation of the alcohol into acetic acid; whereas, with the former, the case is different, because the whole of the nitrogenous matters are completely deposited on the fermenting floors, and being thus thoroughly purified from such substances as tend to cause a fresh fermentation, the liquor when racked is secure against decomposition, notwithstanding that it may have been exposed to 70° or 80° Fahr.

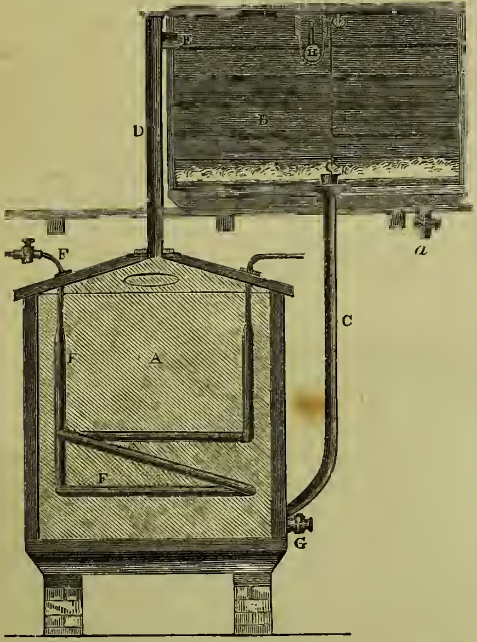
Among the home improvements, the first which was brought to the brewer's aid was the attemperator; this apparatus consists of a coil of metallic tubing placed in the tun, and through which cold water circulates, in order to lower the temperature of the gyle when, from the force of the internal action, it rises too high. This apparatus is now universally employed, and greatly contributes to insure the success of the operation.

The double fermenting square is another of those contrivances which have acquired some celebrity in Yorkshire and the adjoining counties. It consists of an inner close square, with an exit pipe from the cover, through which the barm escapes. In this the worts are inoculated with the ferment, and the space between its walls and those of the exterior square is filled with cold water, by which the temperature of the enclosed liquor is maintained at a low point, and hence the fermentation, though slow, is more sure in its effects. It is controlled, however, with much difficulty, unless there is sufficient spring water at command, especially in summer weather, when cistern or surface water acquires a heat of between 60° and 70° Fahr. The brewer's main endeavor is to keep the fermentation at about 62° to 64°, till the attenuation has been continued as far as is desirable; then, by transmitting cold water into the exterior chamber, as well as through an attemperating pipe placed in the liquor, the heat is reduced to about 56°, at which degree it is maintained during the cleansing.

Harvie's patent is another contribution towards the improvement of the fermentation; its great peculiarity is, that it executes its work in close vessels, in addition to which any other compound composed of carbonic acid, and a base such as carbonate of soda, *et cetera*, may be prepared by transmitting the evoluted gas through a solution of the alkali made for the purpose. The apparatus consists of four tuns or covered vessels, connected together by pipes fixed air-tight in the covers, and passing into the liquor from one to another, similar to the plan of Woulfe's apparatus, till, finally, the carbonic acid is transmitted through the solution in the fourth tun, which requires to be saturated with it. The covers may also be taken off at will, and there are orifices for the purpose of admitting the gyle and other ingredients, but these are closed during the fermenting action. When the attenuation is finished, the contents may be drawn off through openings for that purpose near the bottom. During the fermentation, the liquor should not be allowed to pass from one tun to another; and hence the internal action must be subdued by a reduced heat, so as to discharge the whole of the carbonic acid slowly into the fourth tun.

The annexed simple arrangement represents the patent fermenting square of Messrs. Walker and Son, the leading brewers of Warrington, Lancashire, an arrangement which, in the Editor's opinion, answers every expectation in reference to a good fermentation. It consists of two squares, both air-tight; one, A, in which the fermentation is carried on, and the other, B, for collecting the discharged yeast. Both are connected by a pipe, C, which descends from the bottom of B and enters A at the front near the base. Through this pipe the gyle, as well as the yeast, is admitted into the square, completely filling it; then well-fermented ale is poured in, till there is a layer about two inches in depth on the bottom of the yeast-receiver. As soon as the fermentation commences, and the yeast, as yet frothy and partially formed, begins to be discharged, it rises through the pipe, D, issuing from the top of the bevelled cover, and is discharged into the yeast-receiver at E. As the semifluid matter comes off from the lower, the layer of beer in the yeast-receiver descends in its stead, and maintains the proper level, leaving the bottom of the latter by the liquor received from the lower tun, still covered to the depth of one or two inches, and preventing the froth from again passing into it. In this way the operation is conducted till finished. Should the heat of the liquor be too high, it may be controlled by the transmission of cold water through the attemperating pipe, F. Another cylinder, H, through which a stream of cold water is passed, keeps the air in the covered yeast-receiver sufficiently reduced, thereby arresting the carbonic acid gas arising from the action of the fermentation, which, by any other methods in use, in a great measure escapes. This, to all who are conversant with the subject, is known to be very valuable in securing the soundness of the beer, and giving it a tone of warmth, besides rendering it pleasant and agreeable to the palate.

Fig. 164.



At the termination of the fermentation, the yeast which is accumulated entirely in the square, B, is collected by drawing off the layer of liquor which covers the bottom of this vessel, by means of a hose attached to a pipe, seen at *a;* and when this is done, the barm is brushed out through a plug-hole near one of the corners, and passed along a hose into proper vessels. Should the yeast accumulate in great abundance in consequence of an excess of gluten in the gyle, then, by the same course as the preceding, it may be swept out, and the ale drawn off, pumped up once more, and the fermentation continued till finished.

The heat of the fermenting liquor is under complete control, and may be retained at any degree, provided well-water is at hand; but even if this could not be obtained, the heat of the square would not become so elevated as in the ordinary vessels, because, the froth being removed, the decomposition of the sugar is carried on by the equilibrium of its atomic constituents being destroyed in the first instance, and then it continues, notwithstanding that apparently no formed yeast remains in the gyle. From a personal inspection of the method of Messrs. WALKER, the Editor thinks its introduction into general use would be of great benefit to brewers, for not only does it dispense with the necessity of watching and hand labor required in the usual system, saving an immense amount of space in fermenting a large quantity, on account of the compactness of the apparatus, but the brewer can obtain any attenuation he requires, independent of weather or other circumstances; and at its close, the liquor, after being cooled by means of the attemperating pipe, F, is ready to be drawn off through the tap, G, into barrels or hogsheads and sent to the consumers, in consequence of the yeast being removed during the operation. Messrs. WALKER use twelve ounces of barm to each barrel of wort.

Another great advantage of this system, and one which is entirely overlooked in the other methods, is found in the fact, that no such taint as *yeast-bite* can be discerned in the liquor.

Having thus enumerated the principal methods of inducing and regulating the fermentation, the next process in brewing is now entered upon, namely—

THE CLEANSING, which seems to be followed universally wherever patent fermenting utensils, such as those last described, have not been employed. After the fermentation in the tun has flagged, and the chief portion of the yeast has been removed by skimming or otherwise, particles of yeast and glutinous matters still remain held in mechanical suspension in the body of the beverage, and giving it a muddy appearance. Could these be even removed by filtration, the liquid would still appear muddy, since the fermentation has not completely ceased; and as long as this lasts, fresh particles of yeast will be generated, and these will keep the liquor turbid and impure, unless checked in due time. The ordinary practice is to rack off the contents of the tuns into smaller vessels, ranged horizontally, with a bung or orifice open for the egress of solid matter brought up by the gradual development of carbonic acid from the interior; the vessels are kept full with fresh liquor—generally well-fermented ale. In this way the work is carried on till the fermentation entirely subsides, and the ale becomes completely freed from any floating yeasty matter. As the barm rises to the bung-hole, it falls into a trough which conducts it along to a yeast tub, or receiver. The cleansing, when properly performed, is a very important stage; the distribution of the attenuated liquid into small portions has the effect of reducing the fermenting action considerably—so much so, that if the attenuation has not been sufficiently advanced at the time of racking off into the cleansing vessels, very little can be effected in them, and the liquor will remain too sweet. To prevent this, many brewers either briskly agitate the contents of the fermenting square, to raise the yeast which may have been deposited on the bottom, or add a fresh quantity of the ferment to it, and rummage the whole with an apparatus fitted in the tun for the purpose, or by any other contrivance. In either case, the object is to give the ferment a fresh stimulus, in order to counteract in some degree the checking influence of the racking into small quantities, whereby the temperature and other conditions that aid in converting the sugar into alcohol are not a little reduced.

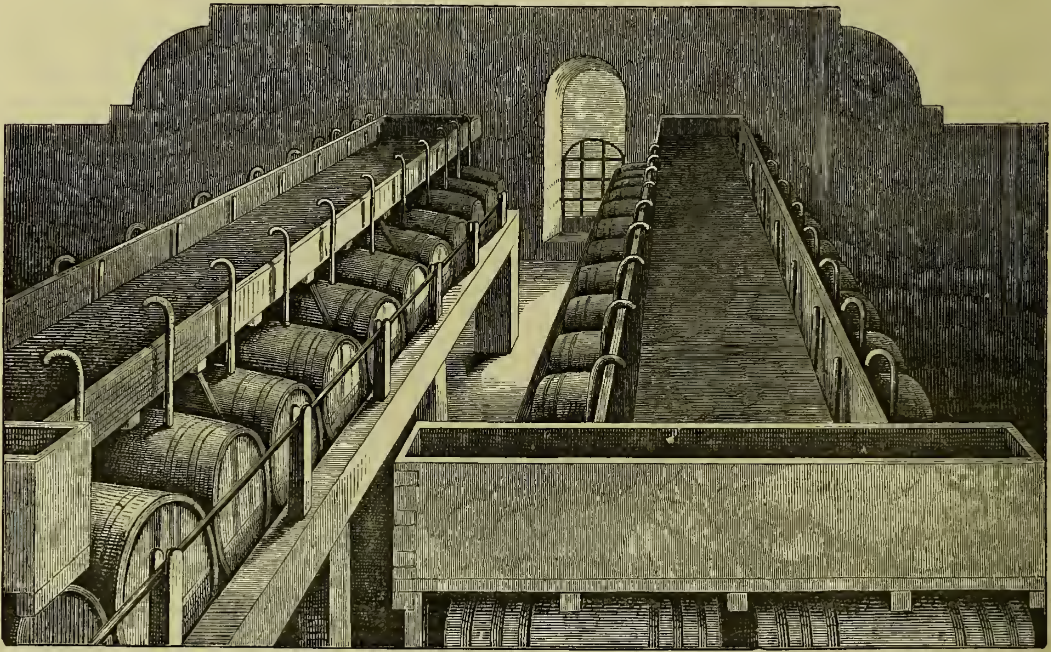
It would, however, be preferable to push the fermentation so far in the tun, as that only enough of saccharine matter will remain to give to the liquor sufficient body, and also, by its slow fermentation, develop so much carbonic acid as to keep it sparkling and refreshing.

In the extensive breweries of Messrs. **Bass** and **Allsopp**, the cleansing is very effectually performed, and for this reason a description of their method will here be given. As already stated, the cleansing has for its object the arresting of the fermentation, and the separation of the yeast, by being transferred into smaller vessels, where it remains for a longer or shorter time, till the clarification is complete. At the above firms there is a number of casks, amounting to 800 or 900, all of which are placed in the cleansing-room for the purpose of depurating the ale. Each of these casks is capable of holding four to five barrels. About ten or twelve of them are suspended on a substantial frame, so as to admit of a free revolution of the casks on their axis. Above these, a large wide open trough—the yeast trough—is placed, with which each of the casks beneath communicates, first, by a movable or sliding tube, and secondly, by a head pipe, usually called a *swan-neck;* the former connection can be cut off at pleasure by a wooden plug. Diametrically opposite these two outlets, a tap is screwed into the casks, and through this the liquor is drawn off when ready for racking. Immediately below these taps, another trough is erected along the whole range, and the liquor is by this means conducted into the racking squares. At one end of the superior trough there is a small reservoir, capable of holding five or six barrels of liquor, and called the *feeder*, in consequence of its being connected with each of the casks by a small pipe running parallel with their ends, and branching off into each; by this means the liquor which separates by evaporation, and also the yeast, are replaced from the reservoir.

Fig. 165 more fully explains this arrangement.

The following is the method of working the apparatus:—The ale to be cleansed is pumped into the large yeast trough, and then run into the casks through the sliding tubes; when the cask is quite full, this communication is stopped up with the wooden plug mentioned before, leaving only the swan-neck outlet free. Through this pipe the froth arising from the fermentation forces its way, and is transferred to the yeast trough, where the yeast is deposited in a manner somewhat similar to the apparatus of **Walker**, noticed in the preceding.

Fig. 165.



To keep the casks full, and to enable the froth to rise to the yeast tun, a quantity of liquor is put into the reservoir, and thence conducted into the casks by the pipe already mentioned. After the fermentation has continued in this state for one or two days, it apparently subsides altogether; the contents are then permitted to remain at rest for a few days longer, for the purpose of affording any yeast that may not have ascended to the trough, time to precipitate to the bottom. The clear ale is then drawn off by means of the screw tap inserted in the lower part of the casks. By turning this tap the interior sucker is so far elevated as to be above the dregs, and therefore none of the impurities are carried off in the liquor, but remain in the casks.

It often happens that the yeasty matter or grounds disseminated through the ale in the casks, does not precipitate, and the consequence is, that it causes the muddiness already noticed to remain. It appears that the composition of the water has a very great influence upon the cleansing of the ale, for when lime compounds are present, the action of the salts inherent in the malt and dissolved in the worts, causes a double decomposition, by which a lime salt is precipitated, and this carries with it the impurities to be removed. The Burton water, as shown at page 244, is remarkable for its adaptation to brewing in this particular, namely, that no finings or other extraneous matters need be added to the fermented menstruum, in order to produce a clear transparent beverage. In a great many instances, where recourse is had to the use of finings, a little more care bestowed upon the preceding operations would do away with the necessity of using them, and it is very questionable whether, in any case, finings or precipitating agents for removing the impurities should be employed.

The substance most generally used for this purpose is isinglass, which is dissolved in sour beer, and then strained through a hair sieve. The consistence of this solution is that of pretty thick mucilage. When a small quantity of it is poured into a cask of the ale or beer, the grounds separate in a very short time, and the liquor remains bright, and free from mechanical impurities.

With respect to the action of the fining liquor on the ale, no very satisfactory explanation can be given Many regard it as spreading over the surface of the menstruum, and forming, as it were, a network, which envelops the whole of the mechanically suspended matters, and carries them with it to the bottom, while the supernatant liquor remains clear; others, again, look upon the floating impurity as being held by the cohesive attraction of the surrounding fluid, in such a condition that, whilst the affinity of the latter is not so powerful as to cause solution, it is nevertheless so strong as to keep it suspended, or in combination; and the fining is supposed to operate, rendering the affinity of the solution for the grounds less, in consequence of being itself dissolved, while it is affirmed that the least derangement of this power is sufficient to insure their subsidence; while some think that, from the fining being lighter, it immediately ascends, carrying with it the deteriorating ingredient, leaving the beer in a clear state. It is evident, however, that there must be a combination of the yeasty matter with the isinglass—whether of a mechanical or chemical nature is not ascertained—it may be a conjunction of both. This is more obvious from the circumstance, that other substances, such as glue, which seemingly partake of the same properties, will not effect a depuration. It would seem also, that the great divisibility of the matter in the beverage, together with a more or less cohesive affinity of the liquid for it, is the cause of its retention; and if this cohesion be in some measure destroyed, by either precipitating the substance, or bringing the particles closer together, so that they may combine from the effect of the attraction among themselves, the liquid will then readily clarify.

Many other bodies, such as albumen of eggs, or serum of blood, react on muddy ale, like isinglass. DONOVAN states that *alum*, in the proportion of one ounce to the hogshead, will purify it thoroughly in a very short time, and without leaving any perceptible taste; he further says, that the dried stomach of the cod-fish, called *sounds*, on being macerated in sour beer, affords a fining liquid equal in most respects to the more expensive isinglass. To dissolve the sounds perfectly, eight or ten days are required, and nothing remains but a small quantity of impurities, which straining through a cloth filter will remove. More or less of this solution will be required, according to the purity of the liquor; but it is certain that, *ceteris paribus*, the less either of this or of isinglass liquid that is used the better, for these substances tend to communicate a flat taste to the product, and prevent it from carrying a good head. When sounds are used, it is better to employ them in summer than in winter; in the latter season, isinglass is to be preferred.

Very many persons, after the fermentation has ceased, instead of cleansing in the way above mentioned, add a fresh quantity of hops, and leave them in contact with the liquor till the whole of the yeasty substance is carried down with them as they subside. The ale, in this case, is improved to some extent by the addition of the fresh hops; but where the custom is to introduce some of the spent hops from a previous operation, the practice is productive of more injury than benefit.

After the clarification, the ale is racked off into store vats, or barrels, to be sent to the consumers; and in doing so, much attention must be directed to the casks and vessels, in observing that they are wholly free from any putrid matter, or bad taste or smell, which would contaminate the ale. The washing of barrels, hogsheads, *et cetera*, is frequently a work of great trouble to many brewers, when the ordinary course is followed. DAVISON, SYMINGTON, PAYNE, and others, have taken out patents for preserving wood, cleansing casks, and so forth, which, to all appearance, are well worth the brewer's attention, but which require too much detail, and are of too mechanical a nature, to be further noticed.

Having thus far given a general view of brewing, and the various causes which affect its success, a few words will now be added on the preparation of particular beverages, and first among these will be noticed—

PALE ALE.—Pale or East India ale is nothing more than beer made from worts extracted from the palest malt, and boiled with the palest and best hops. Every attention is given to the selection of these materials, in order to insure the pale color peculiar to this ale. A great deal of East India pale ale is now used at home, but it differs from that exported, inasmuch as it is less bitter and more spiritous—in every other particular of manufacture and composition they are alike.

The only localities where this excellent beverage is produced in large quantities, are Burton, London, Glasgow, and Leeds. In the latter place, a very large quantity of East India pale ale has for some years been brewed by Messrs. TETLEY and SON; and Messrs. J. and R. TENNENT, of Wellpark Brewery, in Glasgow—one of the oldest and most extensive establishments in Scotland—also prepare pale ale for exportation both to the East and West Indies, commanding in the markets of the latter a large sale.

The peculiar excellence of the ales of the Messrs. TENNENT and Messrs. TETLEY, like those of Burton—both of the latter of which were analysed by the Editor, as also the waters used in their preparation—

is their remarkable keeping quality, and their retention of that delicate flavor of the hops so often lost by the pale ale brewer, notwithstanding his utmost efforts to secure it. This, of course, arises from the near approach made in their practice to the theory, that a low fermenting heat can alone preserve the beer from the simultaneous formation of acetic acid with the alcohol, and their recognition of the fact that 72° Fahr. is the highest degree of heat that can be safely depended upon. Brewing, it is well known, has been long carried on in Bavaria on these principles; but hitherto there has existed an insuperable objection to their adoption by the more extensive firms of this country, on account of the great length of time required for perfect attenuation. This difficulty, however, would appear to be at length overcome, the fermentations being now finished in as short a time as by the old mode; the hop flavor is also preserved, and indeed it may be safely asserted that its delicate aroma is never more surely destroyed than by a high and turbulent fermentation.

This new process of brewing pale ale has also the advantage of affording greater purity of fragrance, it being well known that the dissolution of barm by alcohol, the result of which may often be detected in the yeasty flavor of ale, is much accelerated by high temperatures. Good water, as previously stated, is indispensable in a brewery, for sound ale cannot be brewed with water not adapted for the purpose. The water at the brewery of Messrs. **Tetley** is similar in constitution to the Burton water, as will be seen on referring to the analysis of it, by the Editor, at page 245. That used at Wellpark by the Messrs. **Tennent** has been analysed by Dr. **Penny**, and found to contain the following matters:—

	Grains in the imperial gallon, or 70,000 grains.
Sulphate of lime,	7·2
Sulphate of magnesia,	1·5
Alkaline sulphates,	8·7
Carbonate of lime and magnesia,	8·0
Chloride of sodium,	2·4
Oxide of iron,	·1
Siliceous matter,	·7
Organic matters,	·3
	28·9

Some very excellent bitter ale is now brewed in Birkenhead, near Liverpool, by Messrs. **Cook, Brothers**, who kindly conducted the Editor through their well-regulated establishment—a visit from which he derived many good practical hints. Some of the ales they manufacture, especially those at their Neston works, are very similar to the Burton. The Editor believes that the secret of this superior product is chiefly to be found in the composition of the water, which he analysed with some care, and found to contain large quantities of earthy carbonates and sulphate of lime, without *any organic matter*, which, when existing to any amount, is decidedly deleterious.

Repeated allusions have been made to the methods pursued in different pale ale establishments, in the various stages of mashing, boiling, cooling, *et cetera*, already explained, and, therefore, a recapitulation of these is unnecessary.

The only particular which requires to be noted, in addition to what has been already said, relates to the use of the hops, which, in making this beverage, are added in larger quantity than for the manufacture of the common ales. **Roberts** states that the proportion of hops varies from twenty to twenty-two pounds per quarter of malt; but, considering that the density of the worts is not so high as in many other instances, being about 1·055 specific gravity or upwards, the above proportion must in the majority of cases be very considerably more than the brewers of the present day employ. About sixteen pounds per quarter may be taken as the average allowance, but more or less within certain limits may be used—according to the special object of the brewer—in making a richer beverage, or inoculating the ale with a larger proportion of the bitter ingredient. Considerable care is exercised by the pale ale manufacturers, in having the worts well boiled with the very best hops, so that all the valuable constituents of the flowers may be taken up in the gyle; hence, it is not unfrequent among the Burton brewers to continue the boiling for a period of two hours and a half or three hours. The cooling and pitching heat of the gyle are the same as have been described; and the fermentation and subsequent cleaning have also been fully explained. As, however, the routine and materials employed might affect the fermentation, it may be well to offer a few observations upon this subject.

In making pale ales, the fermentation should be restricted within the range of 60° to 68° or 72° Fahr., according to the degree of heat at the pitching, and the state of the weather. From the beginning of the attenuation, till about three-fourths of the sugar are converted into alcohol, nothing further is required than to observe that the heat is gradually progressing in proportion to the attenuation. After this, greater vigilance must be observed in skimming off the yeast, and checking the action of the ferment, so that the further decomposition of the remaining portion of the sugar may take place at a declining temperature, during which the cleansing can be thoroughly executed.

When this is finished, and the clarified liquor is racked off, it is customary to allow it to rest for eighteen or twenty hours, in order that it may become more clear. It is then run into the casks, barrels, or hogsheads, as the case may be, which, when filled up to the bung, are shived or bunged tightly, and conveyed to the stores or consumers.

It is of great importance that the ale should commence a slow progressive fermentation in the cask, to retain its sparkling and brisk qualities; and to insure this, so much saccharine matter must be left in the liquor, as will, by its conversion into alcohol and carbonic acid, communicate and keep up the requisite briskness; otherwise, if all the sugar were fermented in the first instance, and nothing left to develop the carbonic acid afterwards, the beer would be characterized as flat; while, if it retained nitrogenous matters, and were conveyed to hot climates, it would in a short time become acid and putrefy.

Much of the success of the pale ale manufacture depends upon the care that is taken in selecting the best materials for its composition. It must also be understood, that the several operations through which the malt and hops have to pass, as described in the preceding pages, must be performed with great attention, so as to preserve the color, taste, and other properties of the ale in their fulness and purity.

In the immense establishments at Burton-on-Trent, especially those of BASS and ALLSOPP, where each process is under the strictest surveillance, it is really beautiful to remark how much caution and precision are exercised in every department; it is owing to this, collaterally with the qualities of the water, that the Burton ales have been rendered so justly popular as beverages, and so highly recommended by physicians for their tonic properties.

SCOTCH ALES.—These ales were at one time in considerable repute, possessing a peculiar sweetness not noticed in other beverages. This—especially as regards the Alloa ales—was owing to the addition of Russian honey to the liquor, a practice which has now been abandoned for many years. It is customary with the Scotch brewers to distinguish the quality of their ales by the price; thus, there are three guinea, four guinea, six guinea, and so on to ten and twelve guinea ales, but the latter are rarely brewed. The routine of mashing is mostly the same in Scotland as that usually followed by English brewers. The principal points of difference will appear from the annexed particulars gleaned from one of the most intelligent, expert, and extensive brewers in Scotland.

The density of the wort depends, of course, upon the quality of the ale to be produced. The following are the densities adapted to the different qualities, reckoning by ALLAN's saccharometer:—

For 3 guinea ale the density is about.. ...	65°
“ 4 “ “	80
“ 5 “ “	95
“ 6 “ “	108
“ 8 “ “	115
“ 10 “ “	125

In preparing the worts of four guinea ale, two barrels of water at 175° Fahr. are generally taken per quarter of malt and mashed; this is then sparged over with two and a half barrels of water at 190°. For the other varieties the same amount of water is taken for the mash, but the quantity used in the sparging is less in proportion to the density which the product has to indicate; thus, for five guinea ale, the sparging is made with two barrels, and with one and a half for six guinea ale, whilst the spargings are not added at all in preparing the richer ales. Properly speaking, only one wort is drawn in Scotland, but the lengths of sparging, as just shown, make up for the after worts of the English brewer.

The hopping and boiling of the worts likewise vary but little from the practice already pointed out:—

4 to 5 pounds of hops per quarter are used for 4 guinea ale;
5 “ 6 “ “ “ 5 “
6 “ 7 “ “ “ 6 “

and so on; the period of boiling is from one to one hour and a half with the better class of ales, but is prolonged to two hours, or longer, when the product is poor. The criterion in this, as well as in those instances already alluded to, is the breaking of the flocculent matter, which the attendant carefully watches, and tests occasionally by taking samples in a small vessel, and observing if the flocks readily precipitate. The cooling is performed in the usual way. The pitching heat is about 57°, though sometimes it is reduced to 56° or even 54°; and the period of attenuation extends from eight to twelve days, according to the weather, during which the heat rises to about 70° or more, but never higher if possible than 72°. The extent of the attenuation varies from half to two-thirds of the original gravity. The cleansing of Scotch ales differs in nothing important from the usual system. It may be stated, however, that in Scotland the attenuation is finished in the fermenting tun.

The practice of adding flavorings in the shape of berries, *et cetera*, is now entirely discontinued in Scotland, at least among the more respectable brewers.

PORTER.—Previous to the year 1730, the malt liquors principally drunk in London were ale, beer, and twopenny, and it was usual for the customers to call for half-and-half, that is, half ale and half beer; half ale and half twopenny, or half of beer and half of twopenny. In course of time it also became the practice to ask for a pint or tankard of *three threads*, signifying a third of ale, of beer, and of twopenny; and thus the publican had the trouble of going to three casks to get the mixture required. To avoid this, a brewer conceived the idea of making a liquor which should unite the flavors of the three; he did so, and called it *entire*, and as it was a hearty beverage, it was very suitable for porters and other workpeople—hence the name, *porter*.

The manufacture of this beverage constitutes a large and profitable branch of the brewing business, especially in the metropolitan cities. London and Dublin porter stand foremost in point of quality, but even in these some very inferior samples are to be found.

Considerable disparity of working exists in the various porter breweries throughout the kingdom, which arises from many circumstances, such as the taste of the consumers, the nature of the climate, and such like. In theory, however, the work differs little from the course laid down for brewing ale, but, for the instruction of the general reader, such variations as do exist will be briefly pointed out.

As in the case of pale ale, the great difference in porter from common ale, is the variety of materials worked upon. The grist employed by the porter brewer is composed of various species of malt, mixed together in different proportions.

The annexed table gives a view of these mixtures:—

TABLE OF PORTER GRISTS.

No.	Black.	Brown.	Amber.	Pale.	Total.
1	9	0	0	91	100
2	6	34	0	60	100
3	2	30	10	58	100
4	3	25	15	57	100
5	4	24	24	48	100
6	5	0	95	0	100

Of these, preference is given to the last two, as being the fittest for preparing a good porter; in the others, the excess of black and brown malt occasions too much carbonaceous and useless matter in them, from which the porter acquires a disagreeable taste, as if liquorice and similar compounds were mixed with it.

The malt, on being subjected to a high temperature during the drying, undergoes a decomposition, by which the farinaceous portions are deprived of their natural properties, and converted into a more or less charred mucilaginous substance, according to the degree of heat communicated.

In the amber malt, although some slight carbonization has taken place, yet it is not so powerful as to prevent the saccharification of any considerable portions of the starch, and therefore, while the wort prepared from this is much more colored than it would be if obtained from pale malt, the sacrifice of valuable matter is not very great; as, however, the color given to the mash is not so dark as the consumers require, the quantity of black or patent malt is employed to communicate this shade. The amount of the patent malt varies according to the skill of the manager, and the quality of the remaining portion of the grist.

As in the preparation of pale ales, so in porter breweries, strict attention must be paid to the qualities of the materials.

In preparing the worts, generally a stiff mash is made, and after an hour's maceration, a further portion of water at a high temperature is added, making a total of about three barrels of water per quarter of grist. The whole is mashed for a short time after the second addition, and then the tun is covered till the time of racking, which generally happens in an hour or an hour-and-a-half's time. The worts are pumped into the copper, and boiled and hopped in the usual way. The quantity of hops varies with the quality of the porter to be produced, and according as it is, or is not, intended for exportation, so that the manufacturer must be left to the exercise of his discretion. Among the porter brewers, the proportion extends from six to sixteen, or twenty pounds per quarter. The usual period of boiling is an hour and a half; meanwhile the grist is being further exhausted by the addition of more water, so as to have the second wort ready by the time the contents of the copper are turned into the hop-back.

The hops used in the first boil, and which are not entirely deprived of their virtue, are in many establishments returned to the copper with the second wort, the whole retained at the temperature of ebullition for two hours, and then discharged to the hop-back, from which the gyle flows off, and is cooled down afterwards previous to fermentation.

Before proceeding further, it may be well to make a short allusion to the temperatures at which the mashings are performed. In consequence of the slight degree in which the malt is carbonized or decomposed, the tendency to set or form a coagulum is not so great as when pale malt is macerated in the water, and therefore the temperature of the liquor may be to some extent higher than if the pale malt were operated upon. The reverse of this was supposed to have been the case for a long time, but the truth was at length elicited. Nevertheless, when the large proportion of pale or amber malt is used, the brewers content themselves with the application of water at 160° or 165° for the first mash, and in the second, the liquor has a temperature of 170° to 180°. These heats are subject to a variation of 5° or more, according to the judgment of the manager, and the composition of the grist.

Porter gyle, after being cooled, has usually a specific gravity of 1·052 to 1·081, varying with the intended price of the beer. The fermentation of porter gyle should be vigorously carried on, till the attenuation has advanced to about two-thirds the original gravity; this will take place, according to circumstances, in from two to four days, the temperature rising from 10° to 15°. As soon as it is observed that the heat remains stationary, the preparation for racking off the beer to the *rounds* for the purpose of cleansing is entered upon. Here the barm is discharged and collected in a proper recipient, either by the use of such an apparatus as that at BASS or ALLSOPP'S, noted on a previous occasion, or by the ordinary method. As soon as the sensible fermentation has ended in the rounds, the beer is either pumped into large open receivers, where it deposits a considerable quantity of the *lies* or *grounds*, or is sent to the store vats to be matured.

Such is the usual routine for the preparation of porter, but much more is necessary, or is at least deemed so, subsequent to these operations, in order to make the porter suitable to the different markets for which it is destined, but reference will be made to this afterwards. When the beer does not clarify spontaneously, isinglass is generally applied as a fining agent. Porter intended for keeping or for shipment to warm climates, requires to be as free as possible from any dregs or yeasty matter, and well seasoned. Nothing will assist the brewer in this particular so much as the choice of the best materials.

Good porter has generally the following characteristics:—It is perfectly bright, dark-colored, brisk or well impregnated with carbonic acid; light; sufficiently bitter to the taste; and free from too much acidity.

According to the opinion of several in the trade, the Excise regulations, as at present existing, depress their operations very much, in consequence of the duty being levied upon the malt, on the assumption that it will yield four barrels of beer of 19·4 pounds per barrel, or specific gravity 1·054.

Laying down eighty-four pounds as the maximum yield of a quarter of porter grist, this amount cannot be far from the truth, and according to many brewers the produce is more frequently eighty pounds than otherwise; indeed, considering the loss in boiling, hopping, and fermenting, it is evident that the forementioned produce cannot be fully obtained. No drawback is allowed by the Excise upon the difference of the quantity upon which duty is levied, and that actually obtained; hence it is very evident that the manufacturer suffers.

Mr. CROCKFORD of Long Acre has recently patented a machine for mashing, which he denominates *the Archimedean Attemperator*.

The improvements involve but a small outlay, as they can be readily adapted to the mash-tuns—with or without machines—already in use, and may be worked by either steam, horse, or manual power.

The advantages to be derived from the attemperator are as follow:—

1. The great precision with which the heat can be regulated, whereby every part of the mash can be kept at the same temperature, and this condition prolonged for an indefinite period.

2. The wort can be made to circulate constantly

through the grain, effectually removing the saccharine matter as it is formed, and at the termination of the process it becomes perfectly bright.

3. The apparatus is said to be incapable of derangement, of great durability, is free from valves, *et cetera*, is easily constructed, and no part of the heating apparatus comes in contact with the grain.

4. The extract obtained by the Archimedean process affords a considerable increase over that produced by the present system.

Besides these benefits, the time of brewing is reduced one-half, and much less liquor is required to obtain the whole extract, than by the methods at present in use.

The machine has hitherto given the greatest satisfaction at the breweries where it has been employed.

ADULTERATION OF BEERS.—This subject, fortunately, is not so difficult to deal with at the present day, as it was about half a century ago; whether this result is owing to the increased morality of the brewer, or to the vigorous measures taken by Government in detecting and punishing sophisticators, is a difficult point to determine; but certain it is, that the ingredients which are said to have been employed at that time are positively frightful to contemplate.

The causes of such adulteration might, with truth, be said to originate with the consumers, some fancying a pale liquor, whilst others prefer an amber or brown.

At one time the close approximation of the color to black, was imagined to be a sure sign of perfection.

To communicate such a shade, and at the same time evade the duty payable upon the malt, many resources were tried, such as the use of caramel, or treacle boiled down to blackness; elder-berries, Spanish juice, *et cetera;* and these continued to be used for a considerable period. Caramel, or burnt sugar, and liquorice, are said to be employed at the present day, notwithstanding that all these adulterations are strictly prohibited by law, under a heavy penalty. In the other departments of the manufacture, especially in the means employed for preventing acidity, raising of a creamy head, and giving a semblance of age to the product, many brewers have recourse to such substances as *salt of steel*, or sulphate of iron, chalk, or other earthy carbonates or alkalies.

When the beverage is made from good materials, and with proper care in the fermentation, it remains sufficiently viscid from the gummy matter and sugar in solution, so that, in pouring it from one vessel to another, it gathers on its surface a close creamy foam or head, which, when blown aside, readily closes again. This is more particularly the case with good porter; but when the body or unfermented matter of the beverage is in small or insufficient quantity, this does not take place, and the bad quality of the liquor is thus detected by the consumer.

In order to conceal this inferiority, and give an appearance of richness, the brewer very often, but the vender repeatedly, adds more or less of *heading stuff*, made of isinglass and sour ale beaten well together, introducing a small quantity of this with an ounce or two of sulphate of iron into each hogshead. This has the effect of raising a froth upon the liquid, and also of making it to close immediately when blown aside. By the use of chalk, beer which has become sour may be deprived of its acidity, but it will never be palatable after such treatment, especially if the quantity of acid in it is rather large. When such happens, especially in the porter establishments, the practice is to mix the sour with fresh-brewed beer, and send it to the consumers at once as old porter. Many other ingredients are said to be mixed with beer, particularly by retailers, whereby the bitterness, the stupefying properties of the liquor, and even the thirst of the consumer, is increased, but such adulterations have not come within the range of the Editor's experience. It is asserted, however, that even in breweries, many herbs and seeds, such as wormwood, India berry, or *cocculus indicus*, the fruit of the *Picrotoxia*, or *Menispermum cocculus*, a plant containing an active poisonous principle, *picrotoxin*, and various others, are employed to impart bitterness. Of the articles used to mix with beer, many are harmless; while others, as cocculus indicus, *et cetera*, are highly injurious.

ANALYSIS OF BEER.—This is of much importance to the brewer and toxicologist; to the first, it becomes a means whereby he learns the composition of the worts or gyle of his neighbor, and his precise method of operation; to the second, it is of great consequence, as it detects the poisons administered in malt liquor, by means of which many dreadful crimes, causing an enormous sacrifice of human life, are committed. It is of further importance to the exporter to be able to analyse his beer, and from the results to deduce the original gravity of the wort; for by Act 10th Victoria, cap. 5, a drawback is granted of five shillings per barrel of thirty-six gallons upon beer exported, of which the worts used before fermentation are of not less specific gravity than 1054, and not greater than 1081; and a drawback of seven shillings and sixpence upon beer exported, the worts of which, before fermentation, were not under 1081 specific gravity.

The constituents most necessary for the analyst to determine in this case are, the alcohol, water, saccharine, glutinous, and bitter extractive matter of the hop; but a complete investigation of these will sometimes be necessary for the purpose of detecting any foreign or destructive principle introduced as an adulterant. Much may be learned from an attentive examination of the beer previous to its being submitted to analysis. It should be perfectly clear; turbidness shows that either the acetic or vinous fermentation is going on. The smell and taste of the hops, and the quantity of carbonic acid, which may be judged of from the creaminess of the head—unless head matter had been employed—afford to the connoisseur a means of judging of the quality of the ale with tolerable certainty.

For excisable purposes, the following is the method recommended for the analysis of beers, so as to find the original density of the wort. An accurately graduated four ounce bottle is provided and filled with the beer to be examined, after which the contents, together with the rinsings, are transferred to a retort to which a condenser is affixed, and the measured bottle is used as a receiver. Distillation is then continued till somewhat more than half the quantity of liquid is drawn over, so as to insure the elimination of the whole of the spirit. The remainder of the measured bottle is then filled with distilled water, and the specific gravity of the mixture taken. If, instead of 1000, the weight should indicate 987, it shows that the weight of the diluted spirit is 13° less than water; this is *the spirit indication of the beer.*

By referring to the Excise tables drawn up for this purpose, the density of the worts producing it will be ascertained to be 59·4. The residue in the retort must then be washed with a small quantity of distilled water into the four ounce bottle, which is then filled with water, and the gravity found as before, and its excess over that of water added to the preceding number, plus 1000, and the sum will be the original gravity of the wort. Thus—

If the spirit gravity be..................	59·4
And the extract do.	1030·0
Gravity of the worts,................	1089·4

The annexed table, constructed by Professors GRAHAM, HOFMANN, and REDWOOD, is that by which the Excise are guided in most cases of this description. These numbers in the body of the table indicate the strength of wort corresponding to the spirit indication in the margin.

Degrees of spirit indication	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	0·0	0·3	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	59·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

When a more elementary analysis is required, a portion of the beer is well agitated, so as to dissipate the carbonic acid, and then a certain weight is taken and introduced into a retort connected with a condenser and receiver, and the whole of the spiritous liquor drawn off, and tested by either of the alcoholometric instruments pointed out at page 136, *et sequitur;* the amount of spirit is thus found on reference to the tables of the strengths of alcoholic liquors of different gravities, at page 118, *et sequitur.* The residuary matter remaining in the retort, after the most part of the fluid has been distilled off as just stated, is to be mixed with as much distilled water as will make up the same bulk of liquid as was originally employed, and the specific gravity of this liquid is to be taken by an accurate hydrometer. By this means the quantity of alcohol and extractive matter in the beer is found. To determine the amount of sugar in the solid matter of the beer, a portion of the liquor is weighed and introduced into a flask or beaker, and boiled; if a coagulum should form, it is to be collected upon a dry tared filter, then washed, dried, and weighed. The liquor is next evaporated till it becomes pretty thick; strong spirit of wine, or pretty concentrated alcohol, is then added, causing a precipitate of the gum and mucilaginous matter, which is collected and washed with spirit till all the sugar is extracted; it is finally dried and weighed, and its quantity noted. By evaporating the alcoholic filtrate to remove the spirit, dissolving the residue in water, and boiling the liquid with a grape sugar test solution, made by dissolving—

100 grains of crystallized sulphate of copper,
200 grains of bitartrate of potassa,
800 grains of crystallized carbonate of soda,

in 8750 grains, or one pint of boiling distilled water, and filtering if necessary, a precipitate of suboxide of copper falls, which, when collected, dried, and weighed, affords an indirect but accurate method for ascertaining the amount of saccharine matter, since every three grains of the suboxide indicate one of grape sugar. Having thus ascertained the per centage of albumen—if any—as also of gum and sugar, then, by deducting their total from the quantity of fixed residue, the difference will be the per centage of lupulin, or extractive matter of the hop.

If the beverage was impregnated with any of the products before mentioned they will remain, and be detected as extract of hops. Although a good many of these cannot be recognised by any chemical agencies with which the chemist is acquainted, yet, for the most part, they may be known by their taste, or other physical characteristics. Some of the organic substances, the extract of which is employed to impart bitterness, so closely resemble the hop, that they cannot be distinguished from the latter by any physical tests; one of these is the extract of the picrotoxin.

M. J. L. LASSAIGNE, during his researches upon *picric acid,* has made a distinction between the bitter principle of the hop and this acid. He says that, some time back, the fraudulent use of this acid as a partial substitute for hops had been announced, and that the practice was carried on to a considerable extent in certain districts in France. With the view of finding a ready means for detecting this adulterant in beers, he undertook the investigation. He observes that the taste cannot distinguish between the bitterness of picric acid and the lupulin of the hop; but that, by having recourse to the following experiments, the presence or absence of the adulterant may be readily ascertained. The beer is to be agitated with a solution of subacetate of lead in excess; this throws down a precipitate, consisting of the bitter and most of the coloring matter of the hop, whilst picric acid, *if present,* is unaffected by this reagent, and therefore remains, communicating its peculiar taste to the liquid. Another test, LASSAIGNE remarks, is this, that common bone charcoal, purified by acids, will precipitate and retain the coloring matter of the beer; but that picric acid passes through this medium, communicating its natural tint to the filtrate. Upon these applications he bases the method of recognizing very minute traces of the acid when added to beer.

In his experiments, to prove the efficacy of the test, he operated upon equal portions of a well-made genuine beverage, to one part of which one-twelve or one-eighteen thousandth of the adulterant was added

On pouring into these samples subacetate of lead in excess, or on shaking them with powdered animal charcoal, the pure beer is almost entirely decolorized, whilst the adulterated sample retains *its yellow citron color.* The most minute traces of the adulteration may be detected by evaporating the liquid, and, when reduced to a half or quarter of its bulk, then applying the tests.

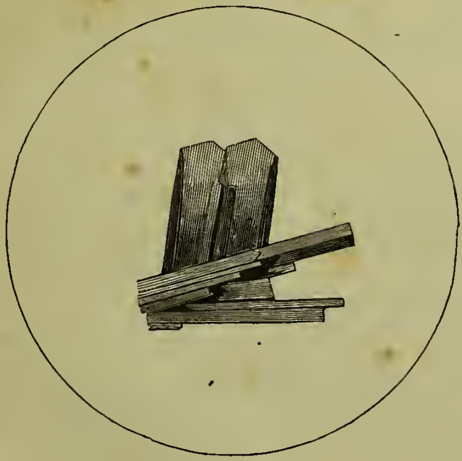
Mr. T. J. HERAPATH has lately published another test for the detection of the active principle of *cocculus indicus* in beers. It is based upon the property which charcoal possesses of separating picrotoxin from its aqueous solution. An excess of acetate of lead is added to the beer under examination, in order to throw down the humulin and other extractive matters; the precipitate is removed by filtration, and the excess of lead in the filtrate abstracted, by transmitting a current of sulphide of hydrogen gas through it, when it will fall down as sulphide of lead. To expel the free sulphide of hydrogen after the filtration of the precipitate, the solution is boiled for some time, then slowly evaporated, until the residue assumes a thick consistency, and a small quantity of pure animal charcoal is agitated with it for a few minutes.

When the whole cools the solution is filtered, and the charcoal, containing the picrotoxin, washed with the smallest possible quantity of water, then dried at 212° Fahr. After all the moisture is expelled, the charcoal is next boiled with some pure alcohol to dissolve the alkaloid accompanying it, the solution is filtered and evaporated, and the picrotoxin permitted to crystallize spontaneously.

If the adulterant be present in large quantities, it is deposited in fine well-formed prisms—Fig. 166—or when the solution is rapidly concentrated, and speedily cooled, the crystals have a beautiful foliated or plumose appearance, similar to Fig. 167.

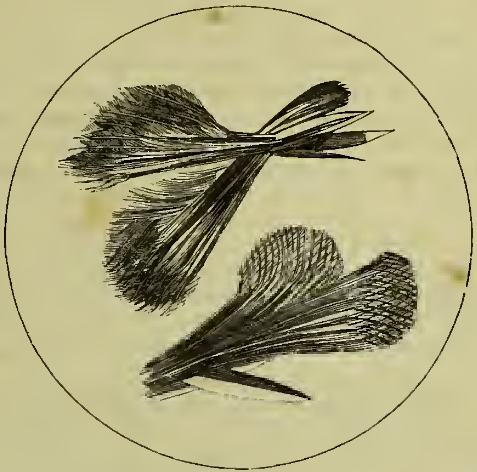
A small amount of this ingredient assumes the form of long radiating needles, which, if the crystallization be conducted as in general between two slips of glass, exhibit a peculiar tendency to place themselves nearly parallel with the edges of the upper glass. See Fig. 168.

Fig. 166.



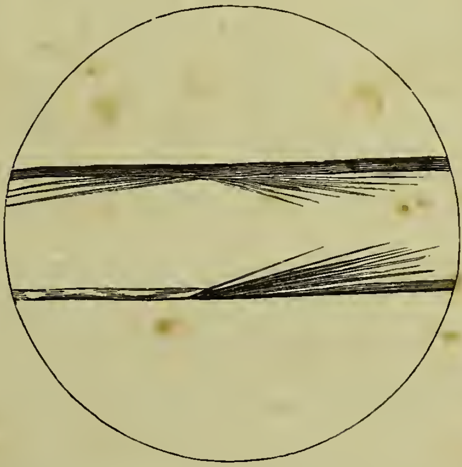
By this means it is said that the alkaloid can be detected in the beer, when only half an ounce of the extract has been added to the barrel.

Fig. 167.



The quantity of acetic and lactic acid in beer is determined by weighing or measuring a certain portion, and neutralizing it with a standard solution of pure carbonate of soda or of ammonia, added gradually from a burette, and calculating the per centage of those acids from the quantity of the test liquor employed. If lactic acid be suspected, another weighed portion of the liquid should be evaporated to dryness, the residue affused with water, and neutralized by the forementioned solution. From the number of measures required, the quantity of lactic acid is calculated. The equivalent of dry lactic acid is 90. By deducting the amount of lactic from the total weight of acid, as above ascertained, the remainder will be acetic acid.

Fig. 168.



Carbonic acid gas may be determined either by boiling a quantity, say a quart of the beer, and collecting the gas in a pneumatic apparatus, or, if this be not convenient, transmitting it into a solution of baryta or lime, and collecting, drying, and weighing the precipitate which it occasions. If lime-water be employed, every fifty parts of the precipitate will denote twenty-two of carbonic acid.

If inorganic adulterations be suspected, their presence may be proved by evaporating the beer to dryness, and incinerating the residue in a platinum capsule or basin, till the whole of the organic matter is dispelled, then dissolving the ash or fixed matter in hydrochloric acid, and testing—for iron, with sulphocyanide of potassium, which will give a blood-red coloration if it be present; for lime, by the addition of ammonia and oxalate of ammonia, which will cause a white precipitate. Should common salt be suspected, it may be proved by dissolving a portion of the residue, after incineration, in water, filtering, and adding nitric acid and nitrate of silver to the liquid; from the bulk of the precipitated chloride of silver, the presence or absence of salt is inferred. Some chlorides are naturally present, so that the formation of a slight opalescence does not prove the adulteration. Should alum be present, it will precipitate in the form of white flocculi, on adding ammonia to the solution when testing for lime.

Owing to its vast importance, the article Beer has been more fully discussed in all its relations, than at first sight it might warrant; but before appending the statistics of this extensive trade, it will, no doubt, prove interesting to the reader to know, that the largest ale establishments are those at Burton, the oldest of which, Messrs. BASS, RADCLIFFE, and GRETTON, brews the enormous quantity of 200,000 barrels per year; a very great proportion of this is bottled and sent to the East Indies. The next well-known house is that of Messrs. ALLSOPP and SONS; and the largest porter brewery in the world belongs to Messrs. BARCLAY, PERKINS, and COMPANY, of London. The three are well worthy of a visit.

STATISTICS OF THE BEER TRADE, SHOWING THE QUANTITIES OF HOPS AND MALT GROWN, MADE, EXPORTED, OR USED IN THE UNITED KINGDOM, AND THE BARRELS OF MALT LIQUOR BREWED UP TO CERTAIN DATES SPECIFIED IN THE TABLES.

Year ending 5th Jan.	British hops.											Foreign hops.								British and foreign hops remaining for home consumption.							Malt made in the United Kingdom. Oct. to Oct.
	Grown weight.				Old duty at 1d. and 15 per cent. per lb.			Exported weight.				Imported.				Exported.				Weight.				Duty at I, 15d. per lb.			
	tons.	cwt.	qr.	lbs.	L.	s.	d.	tons.	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	tons.	cwt.	qr.	lbs.	L.	s.	d.	quarters.
1841	3176	6	0	5	34092	6	2¼	412	8	3	21	5	7	0	12	2	2	3	4	2767	1	1	20	29699	18	0	5,307,107
1842	13617	18	0	10	146165	10	1¾	171	7	3	9	1	14	1	8	6	6	0	17	13441	18	1	20	144276	12	5½	5,105,005
1843	15817	18	1	18	169779	0	3¼	295	18	0	16	—				—				15522	0	1	2	166602	18	10½	4,269,925
1844	12438	14	1	9	133508	17	9¾	130	13	1	25	1	7	2	14	1	0	3	22	12308	7	2	4	132109	18	2½	4,459,673
1845	13073	14	0	4	140324	7	11¾	68	13	2	17	13	7	0	19	1	18	2	12	13016	8	3	22	139709	17	4¼	4,617,247
1846	14720	17	1	17	158004	0	1¼	67	10	0	10	36	6	0	18	36	8	0	26	14653	5	0	27	157278	6	11	4,687,487
1847	22635	14	2	1	242956	15	8¾	200	4	1	21	164	3	1	24	28	17	3	8	22570	15	2	24	242259	15	4	4,987,350
1848	20149	5	1	17	216268	16	7¾	204	0	3	17	73	7	0	22	40	8	3	17	19978	2	3	5	214432	0	7¾	4,345,397
1849	19796	8	1	21	212481	11	10¾	159	7	3	1	19	5	0	23	10	9	1	8	19645	16	2	7	210865	4	5¼	4,913,004
1850	7433	8	3	15	79785	12	8¼	122	13	2	19	263	11	1	14	19	2	0	1	7555	4	2	9	81092	15	9¾	4,749,879
1851	21668	12	0	5	232576	6	7¼	120	15	1	3	324	0	3	22	97	12	0	26	21774	5	1	26	233710	10	10	5,183,617
1852	12072	14	2	15	129580	13	0¾	403	12	0	26	23	1	2	15	46	13	3	24	11645	10	2	8	124995	6	9¼	4,853,118
1853	22813	12	1	2	244866	2	4	426	14	1	9	15	9	0	14	7	15	2	6	22394	11	1	19	240368	6	11¼	5,088,758
1854	14174	17	1	1	152143	10	6¾	358	1	2	15	2115	15	0	27	84	15	0	7	15847	15	3	6	170099	12	3½	5,254,968

The total duty on hops is at the rate of twopence and five per cent. per pound, but the above amounts are calculated at the ratio of one penny and fifteen per cent. per pound weight—called the *old duty*.

The number of quarters of malt fabricated in the year 1841, refers to the quantity from the fifth of January, 1840, to the fifth of January, 1841, and the manufacture of 1854 denotes the total from the fifth of January, 1853, to the fifth of January, 1854.

	Quarters of malt made.		Quarters of malt used.					
			By brewers and victuallers.		By retail brewers.		Total.	
	1853.	1854.	1853.	1854.	1853.	1854.	1853.	1854.
England,......................	4,435,453	4,530,730	3,445,245	3,576,166	481,007	487,128	3,926,252	4,063,294
Scotland,......................	491,474	520,479	150,386	164,677	—	—	150,386	164,677
Ireland,......................	207,134	203,759	160,693	160,929	—	—	160,693	160,929
The United Kingdom,..........	5,134,061	5,254,968	3,756,324	3,901,772	481,007	487,128	4,237,331	4,388,900

From the above table it will easily be perceived that, from the fifth of January, 1853, to the corresponding date, 1854, the increase over the previous year in the quantity of malt made, was in

	Quarters.
England,..............................	95,277
Scotland,..............................	29,005

while in Ireland there was a decrease of 3,375 quarters, showing an increase for the United Kingdom of Great Britain and Ireland, of 120,907 quarters.

The increase in the quantity of malt used by brewers and victuallers in the same period was in

	Quarters.
England,..............................	130,921
Scotland,..............................	14,291
Ireland,..............................	236
Increase in the United Kingdom,........	145,448

The additional quantity of malt used by retail brewers in England is seen to be 6,121 quarters, and the total increase in the consumption of malt in the United Kingdom, 151,569 quarters.

The annexed table exhibits the number of barrels of beer brewed from 1815 to 1829, inclusive.

Years.	Barrels of beer brewed.	Years.	Barrels of beer brewed.
1815	8,169,368	1823	8,081,330
1816	7,985,961	1824	8,087,901
1817	7,131,255	1825	8,511,657
1818	7,221,191	1826	8,701,986
1819	7,549,337	1827	8,306,128
1820	7,184,889	1828	8,529,732
1821	7,471,033	1829	7,737,470
1822	7,683,850		

The duty on beer was repealed in the year 1830, since which date no account of the quantity brewed has been kept; but it is calculated that a quarter of malt, on an average, makes three and a half barrels of beer.

Years.	Bushels of malt used by brewers.	Years.	Bushels of malt used by brewers.
1830	20,790,058	1842	28,856,390
1831	28,717,257	1843	28,537,824
1832	28,417,501	1844	29,593,485
1833	29,566,125	1845	30,180,530
1834	32,139,650	1846	32,841,138
1835	32,830,220	1847	28,970,957
1836	34,235,822	1848	29,275,367
1837	32,186,882	1849	29,954,945
1838	32,323,485	1850	30,919,306
1839	32,073,882	1851	32,570,382
1840	31,887,427	1852	33,944,701
1841	29,408,511	1853	35,111,290

BENZOL.—*Benzine*, French; *Benzol*, German.—This compound, which has been described, from time to time, under the names benzene, benzine, phene, bicarbide of hydrogen, or benzol, is now a special object of manufacture and of commerce.

It may be procured to any extent from coal tar, or from the light naphtha; up to the present time little advantage, however, has been taken of it from either of these sources. Its application in the chemical arts is not extensive, but, from its many and varied properties, it seems calculated to fulfil an important mission; and these considerations induce the Editor to allot to it a separate article, rather than to class it amongst the other products obtained from tar by distillation.

FARADAY was the first to detect benzol as one of the substances emanating from the distillation of organic matter; MITSCHERLICH subsequently showed that it was the principal ingredient in the distillate obtained when hydrate of lime reacts upon benzoic acid at a high temperature. By either of these methods its produce, in any appreciable amount, to be useful in the arts, could not be expected; for, in the first instance, the method by which it was prepared was so imperfect that it could not be prosecuted on a large scale, and in the second, the fact that it was so obtained was more an acquisition to science than to the arts.

Among the many other investigations which have been recently made, that of Mr. MANSFIELD upon coal tar has developed the means whereby benzol can be economically obtained in the highest state of purity.

It is a clear, colorless, and very mobile liquid, having a characteristic agreeable ethereal odor. The boiling point, as stated by MITSCHERLICH, is 186° Fahr., but that prepared by MANSFIELD from the crude naphtha spirit, enters into ebullition at 176°, the ordinary pressure and temperature of the atmosphere being applied. At 32° it crystallizes in masses resembling white wax or camphor, like which it will burn without immediately entering into fusion. By a gradual refrigeration it is obtained in beautiful cruciform leaflets, perfectly transparent, which aggregate into forms resembling fern-fronds, with numerous pinnæ diverging at right angles to a principal axis. Its specific gravity in the liquid state is 0·85; that of its vapor, according to calculation, is 2·738, whilst experiments have shown it to be 2·770. It is insoluble in water, but alcohol and ether dissolve it; hydrated acids have no effect upon it, and the alkali metals, potassium and sodium, when immersed in it suffer no change.

Its composition has been shown by MITSCHERLICH, the Editor, and others, to be that of a hydrocarbon, with the formula $C_{12}H_6$; but the Editor, with many others, thinks it probable, from the facility with which it is converted into nitrobenzol—$(C_{12}H_5)NO_4$—by the replacement of one equivalent of hydrogen by peroxide of nitrogen—NO_4—that it is a hydride of the phenyl radical, namely, $(C_{12}H_5)H$.

In procuring benzol, the course adopted by MANSFIELD was to subject the light coal naphtha, which was drawn over at the beginning of the distillation of the tar, to repeated rectifications, and then to submit it to a cold of 32° Fahr. or under, when it crystallizes. As other compounds, having nearly the same boiling point as benzol, and allied to it in other respects, were suspected to be present, the solid matter was filtered under pressure, with the view of removing them if possible. In executing this part of the work, the operator employed a *Beart's coffee-pot*, as being well adapted for the purpose; and by repeated filtrations under the atmospheric pressure and a low temperature, he succeeded in obtaining a pure product, possessing the properties already enumerated.

As benzol has the same boiling point as alcohol of specific gravity ·825, the author of this research suggests that it may be obtained from the other products accompanying it in the crude light coal naphtha, by similar means to those which are resorted to in rectifying spirit. He recommends the adoption of a metallic retort, which should be surmounted by an open vessel filled with water, and containing a worm or chamber, into which the vapor of naphtha passes directly from the retort, and so arranged that the less volatile fluids, which may be condensed in it, will run back into the cucurbit, or into a separate receiver; while the fluids more volatile than water will flow on to another condenser, which is kept as cold as possible. The water surrounding the head of the still will gradually rise to the boiling point as the operation proceeds, and when this happens the distillation comes to a close, since no fluid remains in the retort, the vapor of which is not condensable at the temperature of the head, which, of course, cannot exceed 212° Fahr.

Rectification of the distillate having been effected a second time, in such an apparatus, limiting the temperature of the head to 176°, and reserving the portions which come over before the heat of the water rises to 194°, a large quantity of a very volatile liquid will be obtained, which, to at least one-half its bulk, will become solid when exposed to a cold of 4° Fahr. By carrying on the distillation as near as possible to the boiling point of the benzol, either by multiplying the condensers, or otherwise, the richer will be the crop of solid matter obtained from the distillate when subjected to cold. This product should be agitated with about a quarter of its bulk of sulphuric acid, or, better still, with about a tenth of strong nitric acid, and, after its removal, with one-fourth its volume of sulphuric. It should then be separated from the acid and distilled, or the distillation may be carried on from the acid, reserving in either case those portions only which pass off under 194°.

The distillate, after agitation with sulphuric acid, should remain perfectly colorless, and the acid should not assume a deeper tint than a straw-brown; if it acquires a darker hue, the product should be subjected to another rectification. When the proper purity has been attained, the volatile liquid should be well washed, first with water, and then with an alkaline lie, to get rid of all traces of acidity. The use of the sulphuric acid in this case, is to remove all the basic substances, to oxidize the small amount of brown coloring matter, and take away such of the neutral oils as form compounds with it. In the latter class, an oil cf an alliaceous smell, more volatile even than benzol, is withdrawn by the acid. By treatment with nitric acid, the same volatile hydrocarbon yields a fragrant oil, the odor of which is not to be distinguished from that of oil of bitter almonds, so that this substance—at present used very extensively in confectionery and perfumery—may now be procured from coal-tar in tons, if required, and at a trifling cost.

The direct purposes which benzol may be made to serve are numerous: it is a very economical solvent for caoutchouc and gutta-percha; and from its great volatility, when the surface of bodies, such as glass or textile fabrics, is coated with the varnish, it deposits on it a very thin film. By these means, artificial cuticles may be formed on the body, which may be serviceable in case of wounds, burns, or cutaneous diseases. It dissolves many resins, mastic, camphor, wax, fatty and essential oils, with great facility. Some resins, such as copal, anime, *et cetera*, which are only slightly acted upon by the liquid, dissolve readily in the vapor at its point of condensation; hence its probable utility for varnish manufactures.

Sulphur, phosphorus, and iodine are taken up by it; the sulphur dissolves best in the boiling fluid, but it precipitates in a crystalline state as the menstruum cools. A current of air transmitted through this liquid becomes so surcharged with its vapor, that when ignited it affords a beautiful white light—in fact, it has been patented by a Londoner as a substitute for coal gas.

Ordinary coal gas passed over the surface of a bath of the fluid, acquires very great additional illuminating power.

Were it not that the price of alcohol is so exorbitant in this country, benzol would be the means of bringing it into use for some illuminating purposes, *et cetera;* for although alcohol and pyroxylic spirit do not afford much light when consumed alone, yet, by an admixture with benzol, they would be made to give a brilliant flame.

Similar mixtures of oil of turpentine and spirit are already in use in some localities in Germany; but benzol, as stated by MANSFIELD, is far more miscible with spirit containing a given amount of water than the oil.

It is an acknowledged fact, that the inhalation of its vapor causes, like chloroform, insensibility to pain, but from some slight irritation which it was found to produce when the experiments were made, it has not yet come into general use as an anæsthetic. Perhaps it may be questioned whether the benzol employed in these experiments was pure.

Benzol may now be considered of some importance, establishments for its fabrication being already at work in Manchester, Glasgow, and other large towns.

BISMUTH.—*Etain de Glace*, French; *Wismuth*, German; synthetically, *tin glass* and *marcasita.* This is one of the metallic bodies accounted *simple* by the modern chemists, though considered a *semi-metal* by the alchemists. Its discovery is of ancient date, being known to AGRICOLA, who wrote about 1530. Its leading features and properties were more fully studied by STAHL, CRONSTEDT, and KIRWAN; but POTT and GEOFFERY carried their investigations further than the others. Subsequently, BERZELIUS examined the metal and its combinations, so that at present its properties are well understood. Its dissemination in the mineral kingdom is not very extensive; in the native state it occurs at Scala, Neritia, Dalecarlia, Altenberg, Schneeberg, Annaberg, Johanngeorgenstadt, Joachimsthal, Baden, Wurtemberg, Hessia, Sweden, and Norway; it is also found in Cornwall and Cumberland in England, and at Stirling in Scotland.

The principal mineralogical combinations of bismuth, besides the native metal, are—bismuth ochre, bismuth blende, bismuth glance, bismutite, tellurii bismuth, bismuth silver, bismuth copper, and needle ore, the latter being a compound of bismuth, copper, and lead, with sulphur.

Of these, native bismuth is the most abundant, and is the body resorted to for the preparation of the element. In the laboratory, the metal is obtained by oxidizing the commercial bismuth with nitric acid, evaporating the solution, and adding a large quantity of water, which throws down a basic nitrate of bismuth. This precipitate is subsequently digested with potassa, to remove arsenious and arsenic acid, the solution filtered, and after the residue has been well washed, it is reduced at a gentle heat with black-flux.

Bismuth is very brittle, of a whitish lustre; but when compared with silver, zinc, tin, and antimony, its aspect is somewhat reddish; it cannot be drawn out under the hammer, but, by delicate treatment, a bar may be slightly extended. It crystallizes in cubes and tetrahedrons. These are best obtained by fusing a large quantity of bismuth in a crucible, and cooling it very slowly, till it assumes a semi-solid consistence; for this purpose the crucible, with the fused metal while red-hot, is embedded in hot sand, and covered over with an iron plate, heated to dull redness, and having some glowing coals placed upon it, to prevent the surface of the metal becoming too rapidly solidified; after a short time the lid is removed, a hole made in the solid crust of the content of the crucible, by holding a glowing coal or a red-hot bar of iron in close proximity, and then the liquid metal is poured out, leaving considerable portions adhering to the sides of the vessel. Upon examining this solid mass, it will be found beautifully crystallized in cubes and hollow tetrahedrons, as before mentioned. By exposure, the crystals instantaneously acquire a slight coating of oxide, which causes them to iridesce. It fuses at from 497° to 508° Fahr., and at a higher degree of heat it may be distilled from close vessels, and condensed in laminæ.

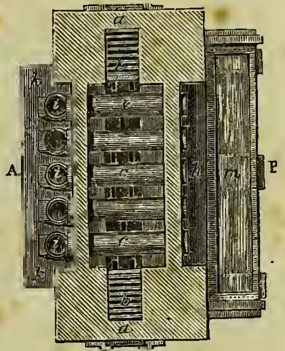
Regnault has stated that the vapor of bismuth is capable of decomposing steam, being oxidized thereby. Heated in the air, the metal burns with a bluish flame, and evolves light yellow fumes. Bismuth is not sensibly affected by exposure to a dry atmosphere; but in a humid, its feeble lustre is readily tarnished.

Pure bismuth has a density of 9·654, according to Karsten, though Marchand and Scheerer state it to be 9·799. The commercial article varies in density from 9·783 to 9·833; but this is considerably diminished by pressure. Booth says that the specific gravity of a bar of bismuth, on being introduced into a steel mortar, and a pressure of one thousand pounds applied, becomes reduced from 9·783 to 9·779; with the application of one hundred and fifty thousand pounds, the reduction comes to 9·655; and with a compression of two hundred thousand pounds, the density is lowered to 9·556. Bismuth has a very defective tenacity, a rod of one-tenth of an inch in diameter bearing only forty pounds; it is also wanting in sonorousness. It has been described as an electro-negative metal; but recent investigations upon its polarity, show that it is affected by electricity. Nitric and nitro-hydrochloric acids dissolve it with considerable energy; but if an electro-negative metal, such as platinum, be brought in contact with it during its solution in nitric acid, the action of the acid is arrested, and the bismuth becomes coated with a black film each time contact with the acid is broken; this blackness, however, readily disappears, and the metal assumes its usual brightness, being now only feebly attacked by solvents. A similar effect is observed if the metal be dipped in nitrous acid, and immediately afterwards into nitric acid. Bismuth decomposes water at a white heat, being converted into teroxide; it takes fire in chlorine gas, giving rise to terchloride of bismuth. It combines with most of the non-metallic elements, as also its oxide with mineral acids, producing corresponding salts, which, however, are not very interesting to manufacturers, though very much so to the scientific chemist. Bismuth is denoted by the symbol Bi; and the atomic or combining weight is 213.

It is for the most part a secondary-product in metallurgical operations, as it is nearly always found, though in the native state, blended with more or less cobalt, silver, arsenic, *et cetera*. Eliquation, conducted with care, is all that is necessary to obtain the metal as sold in the market. The method of conducting this eliquation, the uses of the metal in the arts, and some of its more important combinations, will now be described. These will be found to consist in its alloys, oxides, and nitrates, the latter being chiefly employed for pharmaceutical purposes. A few remarks on the methods of detecting bismuth in combination will conclude the article.

Eliquation.—Cast-iron retorts placed obliquely, and heated by a furnace beneath them, are used for this purpose; and the bismuth of the ore with which these retorts are charged is fused, and flows along the inclination into an appropriate receiver, leaving siliceous and other impurities. The furnace constructed at Schneeberg is represented in the annexed Figs. 169, 170, 171; the first of which is a plan; the second a front elevation, at *k k*—Fig. 169—and the third a section, at A B—Fig. 169.

Fig. 169.



In the plan—Fig. 169—the fire-door is represented by *a*, the grate by *b*, and the eliquating pipes by *c c c*, which are made to incline towards the iron pans, *i i i*, where the fused metal is collected. A wall, *k k*, supports the pans; and to prevent the metal from forming an alloy with the latter, and also to obviate its oxidation, it is customary to throw a little charcoal powder into each. At *m* a tank of cold water is situated, into which the slag remaining in the pipes after the metal is separated from it is drawn. In doing this, the heated matter does not splash at once into the water, but falls along by a declivity, *h*. This arrangement is shown in elevation—Fig. 170—which is a section of the preceding, the same objects being distinguished by the foregoing letters. The pipes, *c c*, are closed at the depressed end by clay plates, denoted by *f* in the section, excepting a small opening through which the fused metal issues to the receivers, *c*; and a

Fig. 170.

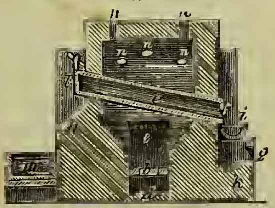
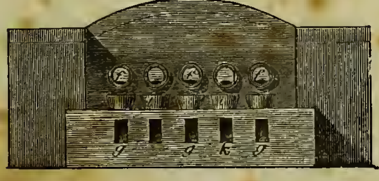


Fig. 171



stout cast-iron door-plate, *l*, secures them at the other. The retorts are heated by the fire, *e*, with the assistance of flues passing from it round each severally, as seen in Fig. 170, and Fig. 171, at *g g*. The draught of the furnace is increased at will by opening the holes, shown at *n n*, Fig. 170, placed between each pair of retorts.

The ore is prepared by breaking it up, and removing the very impure portions; this being effected, about half a hundredweight is introduced into each of the retorts, the door-plates, *l*, made secure, and the fire stirred up to communicate the required degree of heat. This charge should only be about three-eighths of the capacity of the retorts, in order that it may be conveniently stirred. After the application of the heat for ten minutes, the metal begins to flow out by the small space in the clay plate, *f*, at the end; and as soon as it is observed to slacken, the contents of the retort are stirred with a rake, a process repeated several times, till the whole of the metal is obtained, which is usually the case in half an hour. The slag, deprived of all the metal, is now raked out of the retorts into the water tank in front, and replaced by a fresh charge. As the pans, *i i i*, get nearly filled, the fused metal is ladled out and cast into bars, weighing each from twenty to fifty pounds.

At Schneeberg, where about ten thousand tons of bismuth are annually produced, wood is the fuel employed, fifty cubic feet of which is sufficient to work off a ton of ore.

As obtained in this way, the metal is generally impregnated with more or less iron, arsenic, sulphur, *et cetera*, which, however, may be removed by fusing with a suitable quantity of nitrate of potassa to oxidize these impurities.

Bismuth required for medicinal or other particular purposes, where purity is an indispensable quality, should be prepared as directed at the commencement.

ALLOYS.—The chief application of bismuth is in the formation of alloys; it readily unites with tin, lead, silver, mercury, and several other metals, producing compounds the density of which is over the mean of the constituents. Such is the characteristic of the alloy of lead and bismuth in equal proportions; it has a foliated texture, is brittle, and of the same color as bismuth. In bell-founding, bismuth is of great use; for, though wanting in sound, it communicates sonorousness in a high degree to the alloy it forms with tin. When these two metals are mixed in the proportion of twenty-four parts of tin to one of bismuth, the alloy is malleable; but it acquires brittleness according as the quantity of the latter is increased. An alloy of bismuth, tin, and lead, was designated *fusible metal* by Sir ISAAC NEWTON, on account of its low melting point, a name which is still retained.

A mixture of eight parts of bismuth, five of lead, and three of tin, melts at 202° Fahr., and, according to ROSÉ, an alloy composed of two parts of bismuth, one of lead, and one of tin, liquefies at 200·75° Fahr.

All these alloys are rendered still more fusible by a slight amalgamation with mercury, and are serviceable for taking casts of anatomical preparations. An alloy of one part of bismuth, two of tin, and one of lead, is employed as soft solder by pewterers; the same has been proposed as a bath for tempering steel instruments, and cake moulds, for the manufacture of toilet soaps.

Bismuth alloyed with other metals has been used to measure heat when applied to particular technical uses, as also to prevent the explosion of steam boilers; for the latter purpose it was first proposed by the French; but although such safety *rondelles* are ingenious, and seemingly calculated to answer the desired end, yet many boilers to which they have been attached have been known to burst before even the fusible bath liquefied. The reason for such sudden reaction is, that the expansive force of the steam developes itself so instantaneously, that the fusible metal could not possibly be affected by it. The composition of the *rondelles* varies according to the pressure of the steam required; they are so constituted as to enter into fusion, and give way to steam of a higher temperature, but considerably under that which would endanger the safety of the boiler.

OXIDES.—Bismuth unites with oxygen in several proportions, but that generally found is the teroxide. The suboxide of bismuth is merely interesting to the scientific chemist; it is, when obtained from the partial oxidation of the melted metal, or when the finely-divided metal is oxidized in the air, in the form of a reddish-brown substance; the same combination of bismuth and oxygen is obtained when the basic nitrate of the teroxide is digested with an excess of protochloride of tin, and the residue washed and dried *in vacuo;* in this state it is of a coal-black color. In the heat of the blowpipe flame, this oxide reacts like the suboxide of copper when treated with microcosmic salt—phosphate of soda and ammonia;—it does not unite with liquid acids, but in the heat it seems to combine with those which are fixed. The oxide of bismuth and its nitrate, and occasionally the subchloride, are the only compounds which are used in the arts. The former is prepared by dissolving the metal in nitric acid, and precipitating the solution by caustic potassa or soda; or by evaporating the solution of the ternitrate to dryness, and heating the dry mass to redness, by which the nitric acid is expelled, and teroxide of bismuth is obtained. This oxide is of a yellowish color, but by heat it is changed to a blackish glass, which assumes, on cooling, a yellow crystalline appearance. The evaporation of the solution of the ternitrate may be dispensed with, provided much water be added to it to throw down a basic nitrate of bismuth in the form of a white powder; by filtering this precipitate, washing with a little water, drying and heating to redness, the oxide is obtained, as in the preceding. A soluble ternitrate of bismuth remains in the liquid filtered from the precipitate already mentioned, as the annexed formula shows:—

$$\underbrace{4\,(Bi\,O_3\,3\,N\,O_5)}_{\text{Ternitrate of bismuth.}} + 6\,H\,O = \underbrace{(Bi\,O_3\,3\,N\,O_5,\,2\,Bi\,O_3)}_{\text{Basic nitrate of bismuth.}} + \underbrace{(Bi\,O_3\,3\,N\,O_5)}_{\text{Ternitrate of bismuth in solution.}} + \underbrace{6\,(H\,O,\,N\,O_5)}_{\text{Nitric acid.}}$$

The formula for this oxide is $Bi\,O_3$; its specific gravity from 8·174 to 8·968; and it contains in a hundred parts, 89·87 of metal and 10·13 of oxygen.

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